Bull. nat. Hist. Mus. Lond. (Geol.) **54**(2): 109–130 Issued 26 November 1998

Caradoc brachiopods from the Shan States, Burma (Myanmar)

L.R.M. COCKS
Department of Palaeontology, The Natural History Museum, Cromwell Road, London SW7 5BD
ZHAN REN-BIN
Nanjing Institute of Geology and Palaeontology, Academia Sinica, Chi-Ming-Ssu, Nanjing 210008, People's Republic of China

CONTENTS

SYNOPSIS. The brachiopod fauna from the Naungkangyi Group and its equivalents in the Shan States, Burma (Myanmar) is described and reviewed, partly from new collections and also from the publications of Reed in the early half of this century. It consists of 37 taxa within 31 genera, of which *Dirafinesquina* (Family Rafinesquinidae) is a new genus, and *Dirafinesquina globosa* and *Leptellina (Leptellina) minor* are new species. The fauna is of Late Ordovician (Caradoc) age. Affinity analysis between this fauna and other contemporary faunas from South China, North China, Kazakhstan, Altai, Wales, New South Wales and British Columbia shows that the Burmese fauna is most comparable with that from South China, and to a lesser extent North China, and very different from New South Wales and British Columbia. This indicates that the Shan-Thai (Sibumasu) palaeoplate, upon which the Shan States were situated during the Ordovician, was close to the South China palaeoplate.

INTRODUCTION

During the early 1970s the then Institute of Geological Sciences of Great Britain (IGS) undertook field work on behalf of the United Nations in the Shan States, Burma (a country often now termed Myanmar) with the prime aim of establishing the nature and economic prospects of lead-zinc-silver mineralisation of the area. The rocks studied were Cambrian to Cretaceous in age, with substantial igneous intrusions, and included the Ordovician Naungkangyi Group and its equivalent rocks from which came the brachiopods described here. These were collected by the IGS survey teams, in particularly A. H. G. Mitchell and B. J. Amos, and sent to the Natural History Museum, London, for identification amongst other faunas. The results, including the preliminary identifications of the brachiopods by one of us (LRMC) were published in two memoirs and accompanying geological maps: Garson, Amos & Mitchell (1976) for parts of the Southern Shan States (AM and BA in Fig. 1) and Mitchell *et al.* (1977) for parts of the Northern Shan States (AM, TM and YA in Fig. 1). The Naungkangyi Group faunas had also been collected in the early years of the century by the Indian Geological Survey, summarised by La Touche (1913), and the brachiopods published in four papers by Reed (1906, 1915, 1932 and 1936); however, Reed described them somewhat in isolation from contemporary faunas in adjacent parts of Asia. The purpose of the present paper is to reidentify and partially redescribe the Naungkangyi brachiopods in the light of modern brachiopod studies, and to compare them with nearby areas, in particular South China.

BRACHIOPOD FAUNA OF THE NAUNGKANGYI GROUP AND EQUIVALENTS

There follows a list of the fauna which we recognise from the Naungkangyi Group and its equivalents. Those taxa with an asterisk (*) are recorded and figured by Reed (1906, 1915, 1932 and 1936) but were not recollected by the IGS team, and are included here only on the basis of our interpretation of Reed's figures. Reed's original attributions are given in square brackets.

**Lingulella* sp. [*Lingula* cf. *quadrata*: 1906: 49, pl. 4, fig. 1].
**Palaeoglossa?* sp. [*L.* cf. *attenuata*: 1915: 8, pl. 2, fig. 5].
**Schizotreta* sp. [*Schizotreta* cf. *elliptica*: 1906: 50, pl. 4, figs 2, 2a].
Plaesiomys taungtalensis (Reed, 1936) [*Orthis (Dinorthis) flabellulum*: 1906: 62, pl. 4, figs 4–6].
**Plaesiomys* sp. [*O. (Dinorthis) porcata birmanica*: 1915: 10, pl. 2, figs 12–13].
**Glyptorthis* sp. [*O. (Glyptorthis)* sp.: 1936: 25, pl. 1, fig. 24].
Nicolella sylvatica (Reed, 1936) [*O. (Hesperorthis)* cf. *laurentina*: 1936: 20, pl. 1, fig. 15; *O. (Wattsella?) pontilis*: 1936: 27, pl. 2, figs 5–7].
Nicolella sp. [*O. (Nicolella)* cf. *actoniae*: 1936: 29, pl. 2, fig. 9].
**N.* sp. [*O. (Plectorthis)* cf. *dichotoma*: 1936: 20, pl. 1, fig. 23].
**N. liberalis* (Reed, 1936) [*O. (Eridorthis) liberalis*: 1936: 22, pl. 1, figs 3, 3a, 4; *O. (E.) kalavensis*: 1936: 23, pl. 1, figs 1–2].

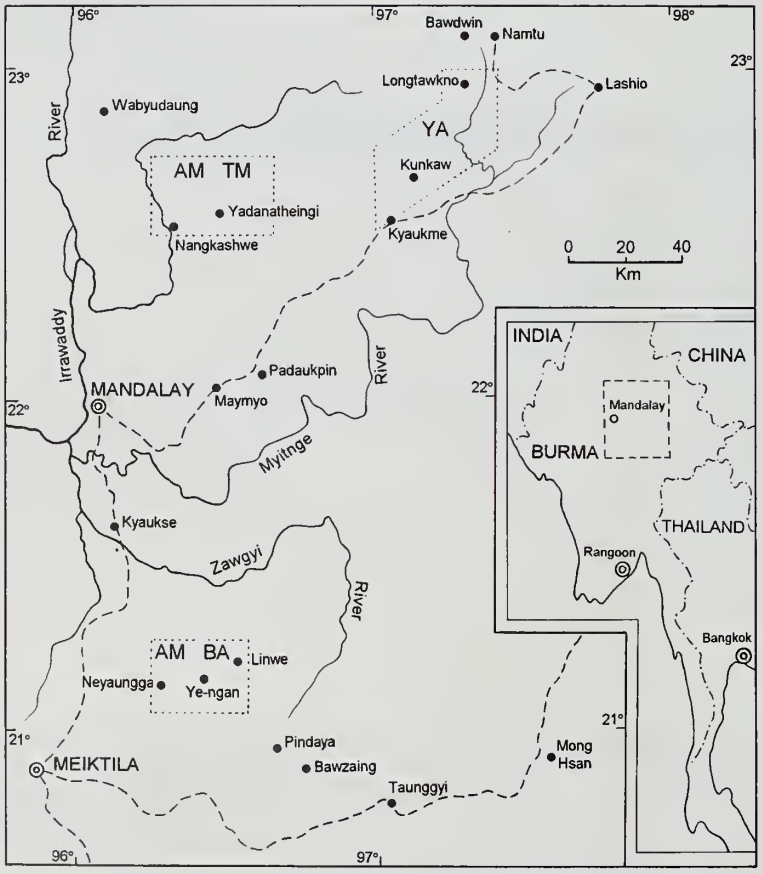


Fig. 1 Location map of Shan States, Burma (Myanmar), with dotted blocks showing the main areas of IGS mapping, which include AM, BA, TM and YA, the prefixes to the new fossil localities and collections described here.

**Ptychopleurella* sp. [*O. (Ptychopleurella)* cf. *lapworthi*: 1936: 27, pl. 2, fig. 4].

Saucrorthis irravadica (Reed, 1906) [*Orthis pustulifera*: 1936: 18, pl. 1, figs 7–14, pl. 2, fig. 3].

Skenidioides sp. [*Skenidioides* cf. *billingsi*: 1936: 68, pl. 2, figs 8, 8a].

**S.* sp. [*O. (Hesperorthis?)* sp.: 1936: 20, pl. 1, fig. 19].

*Indet. draboviid [*O. (Dalmanella) sinchaungensis*: 1936: 28, pl. 2, figs 12–15a].

**Dalmanella?* sp. [*O. (D.) testudinaria shanensis*: 1915: 9, pl. 2, figs 8, 11].

Onniella chaungzonensis (Reed, 1906) [*O. (D.) testudinaria*: 1906: 60, pl. 4, figs 25–26; *O. (D.) testudinaria shanensis*: 1915: 9, pl. 2, figs 6–7, 9–10].

*Indet. dalmanelloids [*Yeosinella consignata*: 1932: 193, pl. 3, figs 1 1a, 2; 1936: 30, pl. 4, fig. 11].

Indet. clitambonitid.

Leptellina (Leptellina) minor sp. nov. [*Leptelloidea (?Leangella)* cf. *derfelensis*: 1936: 43, pl. 4, figs 24–25; *L. (Leangella)* cf. *sholeshookensis*: 1936: 43, pl. 4, fig. 28].

*Indet leptellinids [*Leptelloidea yeosinensis*: 1932: 196, pl. 3, figs 3–6; *L. campestris*: 1936: 42, pl. 3, figs 16–17; *Leptestina?* sp.: 1936: 46, pl. 3, fig. 4].

**Leangella (Leangella)* sp. [*Plectambonites* cf. *llandeiloensis*, Reed 1915: 13, pl. 3, fig. 3].

Bekkerella subcrateroides (Reed, 1906) [*Rafinesquina (Bekkerella) gentilis*: 1936: 38, pl. 4, fig. 14].

Ishimia subdeltoidea (Reed, 1906) [*R. (Kjaerina)* cf. *felix*: 1936: 37, pl. 4, fig. 1].

Ptychoglyptus? shanensis, Reed, 1932: 195, pl. 3, fig. 15.

*Indet. sowerbyellids [*Plectambonites repanda*: 1906: 56, pl. 4, fig. 38; *Sowerbyella* cf. *liliifera* var. *triangulum*: 1936: 39, pl. 4, fig. 10].

*Indet. plectambonitoid [*Plectambonites quinquecostata*: 1906: 55, pl. 4, figs 34–35; *P. sericea*: 1906: 57, pl. 4, figs 36–37].

Bellimurina (Bellimurina?) sp.

*Indet. strophomenids [*Strophomena* sp.: 1915: 12, pl. 3, fig. 1; *Rafinesquina (Kjaerina)* cf. *praecursor*: 1936: 71, pl. 3, fig. 18].

*Indet. furcitellinid [*R. imbrex*: 1906: 52, pl. 5, figs 9–12].

Dirafinesquina globosa gen. et sp. nov. [*R.* cf. *alternata*: 1936: 69, pl. 3, fig. 6; *R.* cf. *semiglobosina*: 1936: 70, pl. 3, fig. 7].

Indet. leptaenines [*Leptaena* cf. *juvenilis*: 1936: 33, pl. 3, fig. 3; *L.* cf. *richmondensis*: 1936: 34, pl. 3, fig. 11; *L. spectata*: 1936: 34, pl. 3, fig. 12].

Glyptomena sp.

Indet. syntrophopsid.

Porambonites spp. [*P. intercedens*: 1906: 68, pl. 5, figs 15, 15a, 15b; *P. sinuatus*: 1915: 14, pl. 3, figs 4–5; *P.* cf. *acutiplicata*: 1936: 48, pl. 3, figs 1–2; *P.* cf. *wahli*: 1936: 49, pl. 3, fig. 15; *Clitambonites* cf. *squamata*: 1906: 66, pl. 5, fig. 14; *C.* cf. *ascendens*: 1936: 31, pl. 3, fig. 14].

Protozyga? haydeni Reed, 1936: 51, pl. 4, fig. 12.

**Cyclospira* sp. Reed, 1936: 52, pl. 4, fig. 13 [?*Hyattidina* sp.: 1932: 206, pl. 3, figs 17, 18].

In addition, Reed figured the following which we find indeterminable, and have therefore omitted both from the above list and also from our faunal analysis of palaeobiogeography (not in this list are other determinations by Reed without any figures):

Ahtiella? sp.: 1936: 47, pl. 1, fig. 20; *Clitambonites* cf. *pyron*: 1906: 65, pl. 5, figs 13, 13a; *Chonetes? thebavensis* sp. nov.: 1906: 57, pl. 5, fig. 16 (perhaps an orthoid); *Gonambonites (Antigonambonites) emancipatus*: 1936: 67, pl. 1, fig. 25; *Ingria?* sp.: 1936: 47, pl. 4, fig. 2; *Leptaena? ledetensis* sp. nov.: 1906: 54, pl. 4, figs 39–41 (perhaps a plectambonitoid); *Leptelloidea* cf. *leptelloides*: 1936: 73, pl. 4, fig. 9; *L. (Leangella?) lamellata* sp. nov.: 1936: 44, pl. 4, figs 22, 23, 23a (indeterminable plectambonitoid); *Leptestia* cf. *musculosa*: 1936: 45, pl. 3, fig. 8; *Orthis calligramma* var.: 1906: 59, pl. 4, fig. 3; 1915: 11, pl. 2, figs 14, 14a; *O. (Dalmanella) elegantula*: 1906: 60, pl. 4, figs 23–24; *O. (Hesperorthis)* cf. *tricenaria*: 1936: 68, pl. 1, fig. 22; *O. (Platystrophia) biforata* var.?: 1915: 10, pl. 2, fig. 15; *O. (Ptychopleurella) pinea* sp. nov.: 1936: 26, pl. 1, figs 18, 18a (indeterminable orthoid); *Petroria* cf. *rugosa*: 1932: 98, pl. 3, fig. 16; *Protozyga?* cf. *obsoleta*: 1936: 52, pl. 5, figs. 9–10; *Rafinesquina* cf. *jaervenis*: 1936: 71, pl. 3, figs 13, 13a; *R.* (or *Leptaena)* cf. *nubigena*: 1936: 72, pl. 1, fig. 16; *R.* cf. *richardsoni*: 1936: 37, pl. 3, fig. 9; *Skenidioides* cf. *billingsi*: 1936: 68, pl. 2, figs 8, 8a, 16–17; *S.* cf. *oelandicus*: 1936: 30, pl. 2, figs 18–21; *Sowerbyella* cf. *cylindrica*: 1936: 40, pl. 4, fig. 15; *S.* cf. *himalensis*: 1936: 40, pl. 4, fig. 3; *S. wilsoni* sp. nov.: 1936: 41, pl. 4, figs 4–8 (indeterminable plectambonitoid); *Stropheodonta* aff. *corrugatella*: 1915: 12, pl. 3, figs 2, 2a; *Strophomena* cf. *subtenta*: 1936: 35, pl. 3, fig. 10; *S. (Actinomena)* cf. *subarachnoidea*: 1936: 36, pl. 3, fig. 5; *Syntrophina* cf. *affinis*: 1936: 49, pl. 1, fig. 17; *Vellamo nemoralis*: 1936: 31, pl. 1, figs 5–6; *V.* cf. ?*simplex*: 1936: 32, pl. 1, fig. 21.

AGE OF THE FAUNA

From the above list, we perceive that the known fauna from the Naungkangyi Group and its equivalents consists of 31 genera, amongst which 32% are orthoids and 42% strophomenoids, and that these two groups are also the most abundant. The absence of rhynchonelloids is an outstanding character of the fauna. Besides the two endemic genera, *Bekkerella* and *Dirafinesquina*, most of the others are limited to the Ordovician, and mostly the Llandeilo to Ashgill. *Plaesiomys* is widely distributed and all its occurences are of Caradoc and Ashgill age, so is *Nicolella*, which is also found in the early Caradoc Shihtzupu Formation of South China. The *Saucrorthis* in our fauna is its first record outside South China, where it is reported only from the Shihtzupu Formation. *Onniella* is of Caradoc to Ashgill age with its acme in the Caradoc. Most of the known species of *Protozyga* are limited to the early to middle Caradoc of North America, north-west Europe and south-east Asia (Copper 1986: 834). *Cyclospira* ranged from the Caradoc to the Ashgill, and was particularly common in the late Caradoc (Copper 1986: 847). *Ishimia* is known from Llanvirn to early Caradoc rocks, *Ptychoglyptus* from the Caradoc to the Ashgill, *Bellimurina* only from the Caradoc and *Glyptomena* from the Llandeilo to the Caradoc. Once again, *Leptellina (Leptellina)*, *Leangella (Leangella)*, *Bellimurina*, *Leptaena (Leptaena)* and *Glyptomena* are also known in the Shihtzupu Formation of South China. Fortey & Cocks (1998) have also discussed the age of the Upper Naungkangyi Beds. Thus the faunas studied here from the Naungkangyi Group and its equivalents in the Shan States are probably of Caradoc age. At what period within the Caradoc these rocks were deposited is less certain. Any age above the early Caradoc would extend upwards the ranges of *Saucrorthis* and *Ishimia*. However, since the Naungkangyi Group is more than 2000m thick, then a variety of ages may be represented.

However, in addition to the faunas discussed above, there are clearly also some earlier Ordovician brachiopods occurring in the Shan States. Reed (1932: 182, pl. 3, figs 7–14) described and figured

what he identified as the new species *Orthis (Dalmanella) emancipata* from Bawzaing, which he listed together with some unfigured molluscs, crinoids and the trilobite *Ogygites* cf. *yunnanensis* Reed. Later he listed and described a further fauna from the Namnoi Horizon, Southern Shan States (Reed 1936: 82), including the new brachiopod *Orthis (Paurorthis) hehoensis* together with trilobites such as undoubted *Annamitella* which Dr R. A. Fortey confirms is restricted to beds no younger than Llandeilo, and is more probably of Llanvirn age. Comparably, also from the Southern Shan States, the Natural History Museum possesses several blocks (BC 52144–52153) from Twinzontaung, collected and presented by T. O. Morris in 1929. These contain hundreds of specimens, mostly external moulds of a monospecific although unidentified orthoid which again has an earlier Ordovician aspect.

There is also the latest Ordovician (Hirnantian) fauna from the Panghsa-pyé Beds, originally described by Reed (1915) and revised by Cocks & Fortey (1997). Thus there are at least three Ordovician horizons present in the Shan States, (a) the Llanvirn-Llandeilo, (b) the Caradoc fauna described here, and (c) late Ashgill faunas from the Panghsa-pyé Beds.

FAUNAL ASSOCIATIONS

Much of the new Naungkangyi material comes from localities AM77 and AM78 north-west of Linwe in the Neyaungga-Ye-ngan area, Southern Shan States (Mitchell *et al.* 1977) at longitude 96°33'E and latitude 21°14'N. The material was collected by A.H.G. Mitchell as blocks, which were split up in the Natural History Museum by one of us (LRMC). Collection AM77 yielded 45 specimens, of which 20 (44.4%) were *Saucrorthis irravadica*, 7 (15.6%) were *Leptellina (Leptellina) minor* and one was *Onniella chaungzonensis*; the remainder were 7 varied bryozoans (15.6%), 9 crinoids (20%) and a single conulariid. Collection AM78 yielded 185 specimens of which 122 (65.9%) were *Leptellina (Leptellina) minor*, 23 (12.4%) were *Dirafinesquina globosa* and one each were *Nicolella sylvatica*, *Glyptomena* sp. and another unidentified orthoid, together with 21 (11.4%) crinoids, 5 (2.7%) the trilobite *Neseuretus birmanicus*, 3 (1.6%) various bryozoans, 5 (2.7%) gastropods of three different kinds, and one conulariid. Even though most of the brachiopods were disarticulated and formed part of a shell hash, the fact that 62 ventral valves and 60 dorsal valves of *Leptellina (Leptellina) minor* were counted in AM78 indicates, nevertheless, that the distance of transportation from the original life habitat to the area of final burial is unlikely to have been great.

All the other material at our disposal were either small collections or single isolated museum specimens from a wide variety of localities. Thus a proper assessment of the associations and hence communities of the Naungkangyi Group must await more substantial systematic collecting. However, even with the small amount of material available, it is clear that the brachiopod diversity of the Naungkangyi Group, although quite large when the Group is considered as a whole, is nevertheless rather small when the individual localities and horizons are considered separately. This diversity is much less than, for example, in the neighbouring Shihtzupu Formation in South China, from which individual beds have yielded over 20 different brachiopods from lithologies which are broadly similar to the Naungkangyi Group. The conclusions reached are that the Naungkangyi associations known to us probably colonized only the shallower parts of the contemporary Ordovician shelf and that the contemporary middle to deeper water faunas are either not preserved or have not yet been found.

PALAEOGEOGRAPHICAL ANALYSIS

The Ordovician was a period of continental dispersal (Cocks & Fortey 1990) and southeast Asia has been recognized as consisting of a number of terranes, one of which is the Sibumasu (or Shan-Thai) terrane including much of the Malay Peninsula, West Thailand, Burma and western Indonesia. The Indochina terrane lies immediately to the east of Sibumasu and the South China terrane to the northeast (Mitchell 1981, Burrett *et al.* 1990). The tectonic boundaries of the Sibumasu terrane are the Uttaradit-Nan to Raub-Bentong sutures to the east and the Shan boundary to the west (Bender 1983, Metcalfe 1992). The Shan States of Central to North Burma (Fig. 1) lie in the western part of the Sino-Burman Ranges. The Naungkangyi Group and its equivalents in the Shan States were deposited at the northern end of the Sibumasu palaeocontinent in the Late Ordovician. From the marine benthic shelly fossils found in these rocks, we can evaluate its relationships with other contemporary terranes. Table 1 shows the faunal affinity indices between eight Caradoc brachiopod faunas calculated by three different formulae as recommended by Rong *et al.* (1995) (for faunal lists see Appendix).

1. The Caradoc Naungkangyi fauna is closest to the early Caradoc Shihtzupu Formation fauna of South China (Xu *et al.* 1974). During the later Caradoc, the purple-red Pagoda Limestone was deposited on the vast area of the Yangtze Platform with a deep-water *Foliomena* fauna quite different from the shallower-water (probably BA2 to BA3 according to Boucot's (1975) concept of Benthic Assemblages) Naungkangyi fauna. There are many common components between the Naungkangyi and Shihtzupu faunas: some genera (such as *Saucrorthis)* are only recorded from these two areas. This confirms that the South China and Sibumasu terranes were not far apart, a relationship which continued into the Ashgill (Cocks & Fortey 1997, Fortey & Cocks 1998).
2. The Naungkangyi fauna shares some similarity with the Caradoc fauna of the Bala District, Wales (Williams 1963), as is shown by the nine common genera, *Lingulella, Nicolella, Skenidioides, Dalmanella, Onniella, Sowerbyella, Glyptomena, Bellimurina* and *Cyclospira*. However, these nine genera are widespread or even cosmopolitan, and thus the data indicate only that the Naungkangyi fauna was faunally connected to many other areas in Caradoc times.
3. Also similar to the Naungkangyi fauna is the one from the late Caradoc Pingliang Formation of Shaanxi, North China (Fu 1982, Rong & Zhan 1996). This fauna overlies graptolitic shales and underlies the even shallower-water Beiguoshan Formation fauna of Ashgill age (Rong & Zhan 1996), and thus represents the transition between shallow and deep water faunas. The constituents in common with the Naungkangyi fauna are *Skenidioides, Leangella (Leangella), Sowerbyella* and *Bellimurina*, but in addition there are some typical representatives of the deeper-water *Foliomena* fauna, including *Foliomena* itself. Since the Pingliang fauna has a comparatively high affinity index with the Shihtzupu fauna of South China, we can postulate that South China, North China and Sibumasu were close together during the Late Ordovician, with North China a little further away from the other two, and that the faunas on them were controlled by comparable environmental factors.
4. The Caradoc fauna from New South Wales, Australia (Percival 1991) has no common constituents with any of our listed contemporary faunas apart from cosmopolitan genera such as *Ptychopleurella, Skenidioides* and *Sowerbyella*. This is also true of the mid Ashgill (Zhan & Cocks 1998), and indicates that Australia

Table 1 Affinity indices between eight Caradoc brachiopod faunas. BUR, the present fauna; SCH, Guizhou, South China; NCH, Shaanxi, North China; KAZ, Chingiz, Kazakhstan; ALT, Gorny Altai, Russia; WAL, Bala, Wales; NSW, New South Wales, Australia; BCC, British Columbia, Canada (for stratigraphy and references see text). Three numbers are shown for each relationship following the different formulae discussed by Rong *et al.* (1995) in the lower left part of the diagram and their averages in the upper diagonal.

	BUR	SCH	NCH	KAZ	ALT	WAL	NSW	BCC
BUR	1	0.3373	0.2557	0.1063	0.1135	0.2752	0.0388	0.0480
SCH	0.3708 0.3600 0.2810	1	0.1842	0.0222	0	0.1726	0.0580	0.0165
NCH	0.2884 0.2800 0.1986	0.2226 0.2222 0.1079	1	0.0800	0.1039	0.3156	0.0997	0.1138
KAZ	0.1391 0.1304 0.0493	0.0626 0.0625 -0.0586	0.1185 0.1176 0.0038	1	0.0178	0.0567	0.0169	0
ALT	0.1437 0.1429 0.0539	0	0.1376 0.1364 0.0376	0.0516 0.0500 -0.0484	1	0.1064	0.1218	0.1410
WAL	0.3036 0.3030 0.2191	0.2050 0.1923 0.1205	0.3490 0.3333 0.2645	0.0873 0.0800 0.0028	0.1352 0.1333 0.0507	1	0.0691	0.0448
NSW	0.0691 0.0678 -0.0207	0.0907 0.0889 -0.0055	0.1325 0.1304 0.0362	0.0497 0.0476 -0.0465	0.1540 0.1538 0.0577	0.0976 0.0968 0.0131	1	0.0517
BCC	0.0784 0.0769 -0.0114	0.0529 0.0526 -0.0562	0.1502 0.1500 0.0411	0	0.1746 0.1739 0.0746	0.0738 0.0714 -0.0107	0.0840 0.0833 -0.0122	1

was in poor faunal contact with South China and Sibumasu in the Late Ordovician, even though they were both parts of Gondwana. The Caradoc faunas from Kazakhstan and Altai are greatly different from the Naungkangyi fauna; a result which is in contrast with the findings of Zhan & Cocks (1998), which indicated that those two terranes were closely related faunally to the South China terrane in mid Ashgill time.

5. The comparatively deeper-water *Bimuria* fauna of North America described by Jin & Norford (1996) from the Advance Formation in the northern Rocky Mountains, British Columbia, has extremely low similarities with any other contemporary faunas compared here, which indicates that all the other seven sites were far away from Laurentia in Caradoc times.

Thus this brachiopod faunal analysis supports Fortey & Cocks' (1998) conclusions that during the Late Ordovician the Sibumasu terrane was closely related to South and North China, and that Sibumasu was closer to South China, in contrast with the latter's closeness to North China in the Early Ordovician.

SYSTEMATIC PALAEONTOLOGY

The figured and cited specimens are deposited in the Natural History Museum, London (BB and BC) and the Sedgwick Museum, Cambridge (SMA). Dimensions (in mm) are L = length, W = width, L_1 = length of cardinalia or ventral muscle field, L_2 = distance of the anterior end of dorsal muscle field away from the umbo, W_1 = width of cardinalia or ventral muscle field, W_2 = width of dorsal muscle field, N = number of ribs, $\propto$ = angle between the socket ridges or brachiophores.

Superfamily **LINGULOIDEA** Menke, 1828
Family **LINGULIDAE** Menke, 1828

Genus ***PALAEOGLOSSA*** Cockerell, 1911

Palaeoglossa? sp.

1915 *Lingula* cf. *attenuata* Sowerby; Reed: 8, pl. 2, fig. 5.

DISCUSSION. *Lingula* cf. *attenuata* was described by Reed (1915) from the Upper Naungkangyi Group (late Caradoc) of Man-ngai, Northern Shan States, and is tentatively attributed to the genus *Palaeoglossa* here, since Sowerby's *attenuata* is now the type species of that genus (Cocks 1978). However, no original material from the Burmese Ordovician is available to us and we are hesitant to identify the species. In addition, Reed (1906: 49, pl. 4, fig. 1) also listed *Lingula* cf. *quadrata* Eichwald from the Naungkangyi Group of Palin, Northern Shan States. This latter might be reassigned to the oboloid *Lingulella* using the differences between *Lingula* and *Lingulella* featured in Williams *et al.* (1965) and Holmer (1989).

Superfamily **ORTHOIDEA** Woodward, 1852
Family **PLAESIOMYIDAE** Schuchert, 1913
Subfamily **PLAESIOMYINAE** Schuchert, 1913

Genus *PLAESIOMYS* Hall & Clarke, 1892

Plaesiomys taungtalensis (Reed, 1936) Pl. 1, figs 1–5

1906 *Orthis (Dinorthis) flabellulum* Sowerby; Reed: 62, pl. 4, figs 4–6.
1936 *Orthis (Glyptorthis) taungtalensis* Reed: 24, pl. 2, figs 10, 10a, 11.

MATERIAL AND LOCALITIES. One dorsal valve (external and internal moulds) from Chaungzon, longitude 96°52'E, latitude 22°21'N; one dorsal external mould from Naungkangale; and two dorsal valves (external and internal moulds) from Pangmaklang (about 20 km northeast of Kunkaw, Locality YA 365, longitude 97°16'E, latitude 22°42'N); all from the Naungkangyi Group of the Northern Shan States.

DISCUSSION. *Plaesiomys* and *Dinorthis* are both large orthoids with relatively small cardinalia and long and elevated sub-triangular to subpentagonal ventral muscle fields (Wright 1964), but the former has multibranching costellae and the latter has simple costae. All the present specimens have branching costellae and small but well-developed cardinalia (about one quarter shell length) with a highly projecting plate-like cardinal process which is limited to the variably-developed notothyrial platform, and so they are included in the genus *Plaesiomys*, although no ventral valves are available.

Reed (1906) described and illustrated three specimens from the Naungkangyi Group at Chaungzon as Sowerby's species *flabellulum* under the subgenus *Dinorthis*, which are the same species as our material in ribbing and dorsal interior. However, the true *flabellulum* (Williams 1963: 363, pl. 3, figs 1–4) has simple costae which only exceptionally branch. *Orthis (Glyptorthis) taungtalensis* (Reed 1936) was named from the Naungkangyi Series of Taungtala, Southern Shan States, and has branching ornamentation, a very convex dorsal valve and small cardinalia limited to the notothyrial platform, which are all present in our material and typical of *Plaesiomys*. *Orthis (Dinorthis) porcata birmanica* (Reed 1915: 10, pl. 2, figs 12–13) is another species from the Upper Naungkangyi Group at Ta-Pangtawng of the Northern Shan States which should be reassigned to *Plaesiomys*, but it differs from *taungtalensis* (including Reed's specimens of '*flabellulum*') in having a more circular shell, denser costellae and a more elongate and anteriorly bilobed ventral muscle field.

The type species of *Plaesiomys*, *Orthis subquadrata* (Hall 1847: 126, pl. 32A, figs 1a–o) from the Richmondian (late Caradoc and early Ashgill) of Ohio, USA, differs from *taungtalensis* in having much denser costellae and a much stronger and larger crenulated myophore. *Plaesiomys robusta* and *Plaesiomys multiplicata*, both from the late Caradoc of Glyn Ceiriog, Wales (Bancroft 1945), are very similar to *taungtalensis*, but can be distinguished by their more rounded shell, denser costallae, and different shape of ventral muscle field. *Plaesiomys porcata* (M'Coy), from the Portrane Limestone (Caradoc), Ireland (Wright 1964: 187, pl. 4, figs 1–12), is different from *taungtalensis* in having an 'isolated' cardinal process (without any notothyrial platform).

Family **PRODUCTORTHIDAE** Schuchert & Cooper, 1931
Subfamily **PRODUCTORTHINAE** Schuchert & Cooper, 1931

Genus *NICOLELLA* Reed, 1917

Nicolella sylvatica (Reed, 1936) Pl. 1, figs 6–10

1936 *Orthis (Glossorthis) sylvatica* Reed: 21, pl. 2, figs 1–2.
?1936 *Orthis (Hesperorthis)* cf. *laurentina* Billings; Reed: 20, pl. 1, fig. 15.
?1936 *Orthis (Wattsella?) pontilis* Reed: 27, pl. 2, figs 5–7.

MATERIAL AND LOCALITY. Four ventral external, six internal, and two dorsal valves (internal and external moulds) from the Li-lu Formation (upper part of Naungkangyi Group) at Ta-Pangtawng (about 10 km east of Longtawkno, Locality YA454.1, longitude 96°23'E, latitude 22°58'N) in the Northern Shan States.

DESCRIPTION. *Exterior*. Semicircular shell 4.5–9.1mm long and 6.8–11.5mm wide with the length/width ratio 0.66–0.79. Lateral profile ventri-biconvex, gently convex dorsal valve with a clear sulcus originating from the umbo. Maximum width along the hinge line which extends laterally, forming a small ear. Curved and small ventral interarea apsacline; narrow dorsal interarea anacline. Anterior commissure slightly sulcate. Ornament of 15–19 simple costae occasionally with some branching in the postero-lateral parts. No median costa on dorsal valve but a pair of comparatively weaker costae appear beside the median groove. Closely-spaced concentric growth lines well-developed on some specimens on the anterior one-third of the shell and showing several typically productorthid imbrications. No exopunctae observed.

Ventral interior. Strong triangular teeth supported by thin, short and subparallel dental plates. Small, elongately oval and weakly-impressed muscle field without any apparent anterior or antero-lateral bounding ridges; the adductor and diductor scars are not distinguishable. Strong ribs on the surface of the shell, reflected on the internal surface of both valves in a series of corresponding deep and narrow radial grooves which include the muscle field; the intervals between grooves are almost three times as wide as the groove. No vascular markings seen.

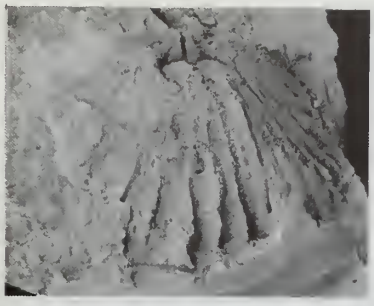
Dorsal interior. Small cardinalia about one-fifth shell length and width; strong cardinal process with a swollen myophore, separated from the brachiophores, occupying the whole notothyrial platform which is slightly elevated; brachiophores triangular at their bases, projecting highly anteriorly and ventrally at about 75° to one another; weak brachiophore supports extend medially and meet at the median ridge to form a low and wide ridge parallel to the hinge line. Poorly impressed muscle field with a low and wide myophragm extending to the anterior margin.

PLATE 1

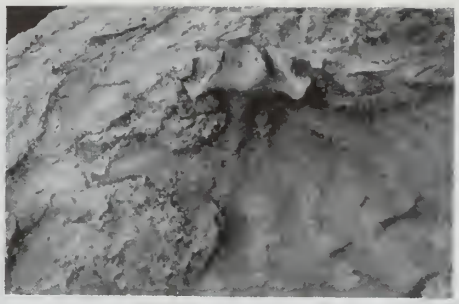
Figs 1–5 *Plaesiomys taungtalensis* (Reed). **1**, BC 52159, Kunkaw, Locality YA43, dorsal internal mould, × 2. **2**, BB 37726, Pangmaklang, Locality YA365, latex cast of a dorsal internal mould showing the cardinalia, × 4. **3**, SMA 3132, Chaungzon, latex cast of a partial dorsal external mould, × 2. **4a, 4b**, SMA 3131, Chaungzon, dorsal internal mould and latex cast, × 2. **5**, BB 37724, Pangmaklang, Locality YA365, dorsal internal mould, × 2.5.

Figs 6–10 *Nicolella sylvatica* (Reed). **6–9**, Ta-Pangtawng, Locality YA454.1. **6a–c**, BB 37738, latex casts of ventral exterior and interior, and ventral internal mould, × 3. **7a, 7b**, BB 37736, dorsal internal mould and latex cast, × 4. **8a–c**, BB 37739, 8a, latex cast of dorsal exterior with a ventral exterior at the top right (BC 52414), × 4; 8b, 8c, latex cast and internal mould of dorsal interior, × 4. **9a, 9b**, BC 52414, latex cast and internal mould of ventral interior, × 4. **10a, 10b**, BB37682, Neyaungga, Locality BA490, latex cast and internal mould of ventral interior, × 4.

Fig. 11 *Saucrorthis irravadica* (Reed). BB37705, Linwe, Locality AM77, latex cast and internal mould of ventral interior, × 4.

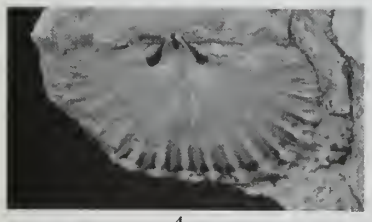


1

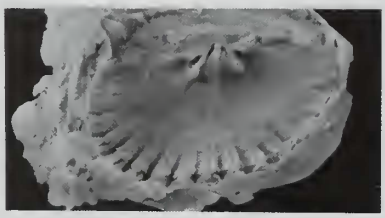


2

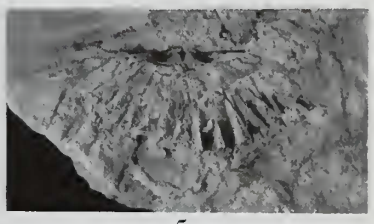
3



4a



4b



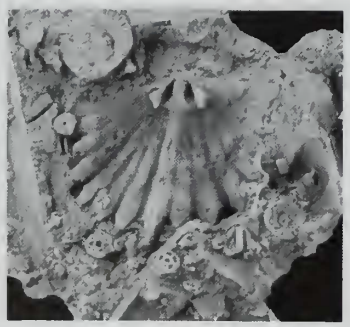
5

6a

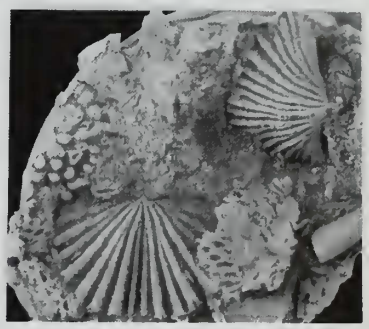
6b

6c

7a



7b



8a

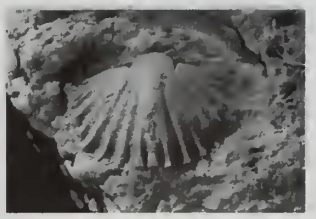
8b

8c

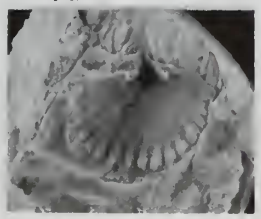
9a

9b

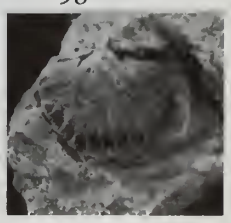
10a



10b



11a



11b

MEASUREMENTS

	L	W	L/W	W1	W1/W	N
BB37736, dorsal valve	6.0	–	–	1.8	–	16
BB37737, ventral valve	5.2	7.0	0.74	2.1	0.30	15
BB37738, ventral valve	9.1	11.5	0.79	3.1	0.27	19
BB37739, dorsal valve	4.5	6.8	0.66	1.3	0.19	16
BB37743, ventral valve	6.2	8.1	0.77	1.9	0.23	15

DISCUSSION. According to Williams' (1963: 352) emended diagnosis, *Nicolella* has a plano-convex shell, an ornament of simple costae with a very few rarely developed costellae, strong teeth supported by short receding dental plates, an elongately oval ventral muscle field without any bounding ridges, and small cardinalia with an elevated notothyrial platform. Both Reed's (1936) illustrated specimen and our present material possess these main characters. The specimen identified by Reed (1936: 20, pl. 1, fig. 15) as *Orthis (Hesperorthis)* cf. *laurentina* Billings is a slightly distorted dorsal valve from the rocks corresponding to the Naungkangyi Group in the Southern Shan States of the same age as *sylvatica*. Its outline, ribbing and concentric growth lines are similar to *sylvatica*, but without interiors is only questionably reassigned here to *sylvatica*. Although *Orthis (Wattsella?) pontilis* (Reed 1936: 27, pl. 2, figs 5–7) has a similar locality and horizon to *sylvatica* and the same exteriors as the latter, its large ventral muscle field and apparent dorsal muscle bounding ridges make us uncertain whether or not it is truly a junior synonym of *sylvatica*.

The type species of *Nicolella*, *Orthis actoniae* J. de C. Sowerby, has been studied and discussed by several authors, such as Davidson (1868: 252, pl. 36, figs 5–17), Williams (1963: 353, pl. 1 figs 15–19, text–fig. 6) and Wright (1964: 165, pl. 2, figs 1–7, 10–11), all from Caradoc material. It differs from *sylvatica* in having more widely divergent brachiophores and in lacking the slight fold and sulcus. *Nicolella delicata* (Xu, Rong & Liu 1974: 151, pl. 66, figs 28–30), from the Shihtzupu Formation (early Caradoc) of Zunyi, Guizhou Province, South China, can be distinguished from *sylvatica* by having well-developed exopunctae and stronger dental plates enclosing a more circular ventral muscle than *sylvatica* and might even be attributable to *Sulevorthis*. *O. (Eridorthis) liberalis* (Reed 1936: 22, pl. 1, figs 3, 3a, 4) and *O. (Eridorthis) kalavensis* (Reed 1936: 23, pl. 1, figs 1–2) are two new species named by Reed on the basis of a ventral and a dorsal valve respectively. Because they are both from the rocks corresponding to the Naungkangyi Group at Taungtala of the Southern Shan States and have similar ribbing and shell sizes, we think they might be the same species and, if so, *liberalis* would be the senior synonym. It differs from *sylvatica* in having much coarser and branching ribs and a sessile pseudospondylium in the ventral interior; however, with the minimal material available, its generic attribution is doubtful.

Nicolella sp.

1936 *Orthis (Nicolella)* cf. *actoniae* Sowerby; Reed: 29, pl. 2, fig. 9.

MATERIAL AND LOCALITIES. Two dorsal and one ventral external moulds from the Naungkangyi Group at Kunkaw; four dorsal and two ventral external moulds from the Naungkangyi Group at Chaungzon, both in the Northern Shan States; and one ventral external mould from the rocks corresponding to the Naungkangyi Group at Neyaungga in the Southern Shan States.

DISCUSSION. Reed illustrated only exteriors, which makes further identification unreliable, although the external morphology is similar to *Nicolella actoniae* J. de C. Sowerby from Shropshire. These Burmese specimens differ from *N. sylvatica* in having nearly flat dorsal valves and branching ribs (costellae) at two-thirds of their shell length.

Genus ***SAUCRORTHIS*** Xu, Rong & Liu, 1974

Saucrorthis irravadica (Reed, 1906) Pl. 1, fig. 11; Pl. 2, figs 1–5

1906 *Orthis irravadica* Reed: 62, pl. 4, figs 15–22.
1915 *Orthis irravadica* Reed; Reed: 11.
?1932 *Yeosinella consignata* Reed: 193, pl. 3, figs 1–2.
?1936 *Orthis pustulifera* Reed: 18, pl. 1, figs 7–14; pl. 2, fig. 3.
1936 *Yeosinella consignata* Reed; Reed: 30, pl. 4, fig. 11.

MATERIAL AND LOCALITIES. One dorsal internal and external, and one ventral external mould from the Naungkangyi Group at Namyun (about 7 km southeast of Longtawkno), Northern Shan States; eight ventral internal, nine external, five dorsal internal and eight external moulds at Linwe (Locality AM77), three ventral internal and external, and four dorsal internal and external moulds from the Neyaungga-Ye-ngan area (Locality BA490), both from the Kinle Siltstone Formation (equivalent to the Upper Naungkangyi Group) in the Southern Shan States.

DESCRIPTION. *Exterior*. Small semicircular shell 2.4–6.6mm long, 3.3–9.1mm wide, with length/width ratio 0.70–0.88. Lateral profile ventribiconvex with dorsal valve gently convex or even flat with a median sulcus. Maximum width invariably along the hinge line. Ventral interarea comparatively large, apsacline, delthyrium open. Very small anacline dorsal interarea without chilidium, but most of the notothyrium is occupied by the cardinal process. Ornament of simple costae and fine concentric fila. Sharp costae generally unbranching, coarser anteriorly, 18 on the dorsal valve and 15 on the ventral valve irrespective of the shell size; no central costa on dorsal valve. In a well-preserved specimen (Pl. 2, fig. 5), minute but distinct

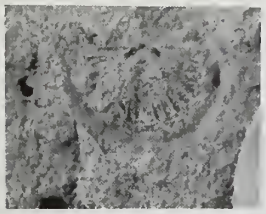
PLATE 2

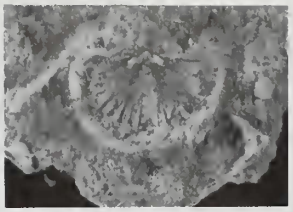
Figs 1–5 *Saucrorthis irravadica* (Reed). **1a, 1b**, BB 37670, Neyaungga, Locality BA490, dorsal internal mould and latex cast, × 5. **2–5**, Linwe, Locality AM77; **2**, BB 37702, ventral internal mould, × 5; **3**, BC 52411, latex cast of dorsal exterior, × 4; **4a–c**, BB 37668, 4a, dorsal internal mould, × 5, and 4b, 4c, latex casts of dorsal exterior and interior, × 4; **5**, BB 37695, dorsal external mould showing sparse exopunctae, × 12.

Figs 6–10 *Onniella chaungzonensis* (Reed). **6**, BB 37676, Neyaungga, Locality BA490, latex cast of ventral exterior, × 4. **7–10**, Ta-Pangtawng, Locality YA454.1. **7a, 7b**, BB 37731, latex cast of dorsal exterior, and dorsal internal mould, × 4. **8**, BC 52412, ventral internal mould, × 8. **9**, BC 52413, latex cast of dorsal exterior with ventral interarea, × 8. **10a, 10b**, BC 52416, latex cast and internal mould of dorsal interior with a ventral valve (BC 52415) of *Nicolella sylvatica* (Reed), × 4.

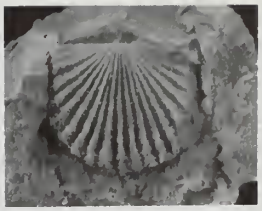
Figs 11–12 Indeterminate clitambonitid. Kunkaw. **11**, BB 37777, Locality YA40.1, ventral internal mould, × 5. **12**, BB 37771, Locality YA39, ventral internal mould, × 3.

Figs 13–14 *Leptellina (Leptellina) minor* sp. nov. Linwe, Locality AM78. **13a, 13b**, BB 37633, dorsal internal mould, and latex cast, × 4. **14a–c**, BB 37643, ventral internal mould, latex cast and posterior view, × 5.


1a


1b

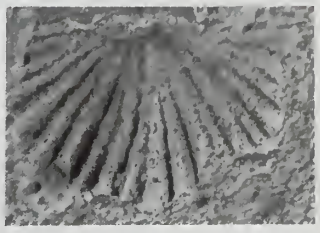

2


3


4a

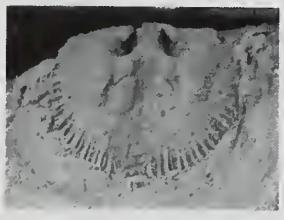

4b

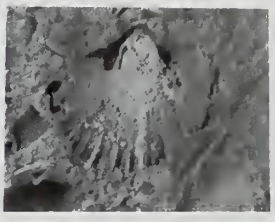

4c


5

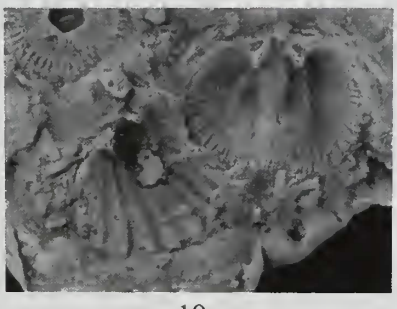

6


7a


7b


8

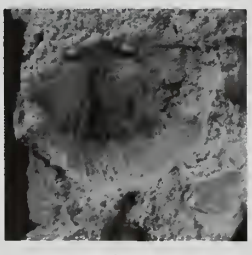

9

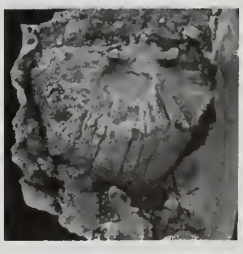

10a


10b


11

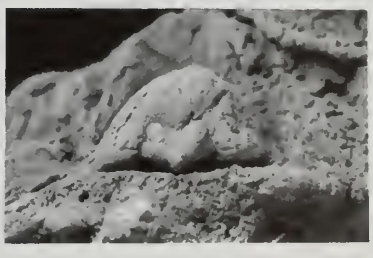

12


13a


13b


14a


14b


14c

exopunctae are visible in lines along the rib crests, with a few additional exopunctae sporadically distributed on the rib slopes.

Ventral interior. Small teeth supported by a pair of very short, subparallel dental plates. Poorly impressed muscle field about 28% as wide as the shell and open anteriorly. Strong crenulations along the peripheral area of both valves about one quarter of the shell length, which form broad, flat to weakly hollowed, scalloped ridges separated by narrow deep grooves.

Dorsal interior. Cardinalia about one fourth as wide and one sixth as long as the shell; small cardinal process limited to the posterior part of the narrow but weakly elevated notothyrial platform, and connected with the posterior ends of the brachiophores on both sides. Well-developed brachiophores triangular at their base, highly projecting anteriorly and ventrally at 90–110° to one another, and supported for their posterior one-third by thin subparallel plates. Weakly-impressed subquadrate muscle field just in front of the cardinalia, composed of two pairs of adductor scars on either side of a low and wide myophragm which becomes wider anteriorly towards the shell margin; the posterior scars always larger than the anterior pair.

MEASUREMENTS

	L	W	L/W	W_1	W_1/W	N
BB37668, dorsal valve	4.7	5.5	0.85	1.4	0.25	18
BB37669, dorsal valve	3.0	3.7	0.81	0.9	0.24	18
BB37670, dorsal valve	2.4	3.3	0.73	0.9	0.27	18
BB37682, ventral valve	4.5	6.4	0.70	1.8	0.28	15
BB37702, dorsal valve	4.7	5.3	0.88	–	–	18
BB37705, ventral valve	4.2	5.2	0.81	1.5	0.28	15
B29665, dorsal valve	6.6	9.1	0.73	2.6	0.28	–

DISCUSSION. The species *irravadica* was named by Reed (1906) within the genus *Orthis* for some small specimens from the Naungkangyi Group at several localities in the Northern Shan States. The illustrated exteriors and ventral interiors (Reed 1906: pl. 4, figs 15–22) are similar to our specimens from the same area and are assigned to *Saucrorthis* especially on the ribbing and cardinalia. *Orthis pustulifera* Reed (1936: 18, pl. 1, figs 7–14; pl. 2, fig. 3), from rocks corresponding to the Naungkangyi Group at Thitteikkon and Konleau, Southern Shan States, is much like *irravadica* in its external characters and cardinalia, but it has better-preserved exopunctae and stronger dorsal muscle bounding ridges and dental plates. The species is questionably included as a junior synonym of *irravadica*. The material identified by Reed (1932, 1936) as *Yeosinella consignata* Reed consists of some dorsal valves from rocks corresponding to the Naungkangyi Group at Ye-o-sin in the Southern Shan States which seem identical to our specimens of *irravadica*. No ventral valves of *consignata* are known, but should they also prove to be the same as *irravadica*, then *Yeosinella* would become a senior synonym of *Saucrorthis*.

Saucrorthis, previously thought endemic to South China, is recorded here from outside it for the first time. The type species, *S. minor* (Xu, Rong & Liu 1974: 151, pl. 66, figs 1–4), from the Shihtzupu Formation (early Caradoc) at Zunyi, Guizhou Province, differs from *irravadica* in having a smaller subquadrate shell, narrower divergent brachiophores (about 75° as compared with 90–110° in *irravadica*), much stronger peripheral crenulations and more developed dental plates. *Sulevorthis*, a small orthid named by Jaanusson & Bassett (1993: 40) with its type species *Orthis lyckholmiensis* Wysogórski from the Lyckholm Beds (Vormsi Stage, late Caradoc) of Kõrgessaare, Hiiumaa, Estonia, is very similar to *Saucrorthis* externally, but its strong cardinal process is elongate, occupies the entire notothyrial cavity and is separated from the brachiophores completely, and no notothyrial platform is developed. Among all the species assigned to *Sulevorthis* by Jaanusson & Bassett (1993: 38), *Orthambonites parvicrassicostatus* (Cooper 1956: 309, pl. 35B, figs 11–25) from the Benbolt Formation (Porterfieldian, early Caradoc?) of Virginia, USA and *Orthambonites humilidorsatus* (Wright 1964: 160, pl. 1, figs 1–12) from the Portrane Limestone (Caradoc) of Ireland are the species of *Sulevorthis* most similar externally to our present material, particularly in the presence of exopunctae.

Family **SKENIDIIDAE** Kozlowski, 1929

Genus ***SKENIDIOIDES*** Schuchert & Cooper, 1931

Skenidioides sp.

?1936 *Skenidioides* cf. *billingsi* Schuchert & Cooper; Reed: 68, pl. 2, figs 8, 8a.

MATERIAL AND LOCALITY. One ventral valve (internal and external moulds), BB 37594, from the equivalents of the Upper Naungkangyi Group at Linwe (Locality AM 78), Southern Shan States.

DISCUSSION. A single broken shell 3.7mm long and 4.7mm wide, with radial costae branching only once within one-third of the shell length and 4 per mm on the shell anterior, a very high interarea and small teeth, is typical of *Skenidioides*. Reed described two species of this genus from the Southern Shan States, *Skenidioides* cf. *oelandicus* Wiman from the Naungkangyi Group at Nam Wabya (Reed 1936: 30, pl. 2, figs 18–21) and *Skenidioides* cf. *billingsi* Schuchert & Cooper from the Bawzaing Horizon (contemporary with the Naungkangyi Group) at Sinchaung (Reed 1936: 68, pl. 2, figs 8, 8a). *S.* cf. *oelandicus* does not appear from Reed's illustrations to be a *Skenidioides* because the ventral interarea is far too small. *S.* cf. *billingsi* is represented in Reed's material by a single ventral internal mould which may or may not be a *Skenidioides* and the same as the present specimen; it is poorly preserved.

Superfamily **DALMANELLOIDEA** Schuchert, 1913
Family **DALMANELLIDAE** Schuchert, 1913
Subfamily **DALMANELLINAE** Schuchert, 1913

Genus ***ONNIELLA*** Bancroft, 1928

Onniella chaungzonensis (Reed, 1906) Pl. 2, figs 6–10

1906 *Orthis (Dalmanella?) chaungzonensis* Reed: 61, pl. 4, figs 7–14.
1906 *Orthis (Dalmanella) testudinaria* Reed: 60, pl. 4, figs 25–26.
1915 *Orthis (Dalmanella) testudinaria shanensis* Reed: 9, pl. 2, figs 6–7, 9–10.

MATERIAL AND LOCALITIES. One dorsal and one ventral valve (both internal and external moulds) from the Naungkangyi Group in the Yadanatheingi area (Locality AM1); three dorsal valves (internal and external moulds), and five ventral internal and four external moulds from the Li-lu Formation (equivalent to the Upper Naungkangyi Group) at Ta-Pangtawng (about 10 km east of Longtawkno, Locality YA454.1), both in the Northern Shan States. One dorsal internal mould from the equivalents of the Upper Naungkangyi Group at Linwe (Locality AM77), Southern Shan States.

DESCRIPTION. *Exterior*. Small transverse shell 2.4–5.4mm long and 2.7–6.4mm wide with length/width ratio 0.75–0.89. Lateral profile unequally biconvex; gently convex dorsal valve with a conspicuous sulcus originating from the umbo, much deeper ventral valve with strongest convexity along the hinge line. Maximum width near the shell midlength. Ventral beak small; slightly curved apsacline interarea; open delthyrium; narrow anacline dorsal interarea; without chilidium but notothyrium occupied by strong cardinal process lobes (Pl. 2, fig. 10a). Ornament of densely populated costellae, branching medially and laterally on dorsal valve and laterally on ventral valve three times: firstly at one-quarter shell length, secondly at one-third length and finally at two-thirds length. No median rib on dorsal valve, but a deep and narrow groove along the median line with a pair of weak costellae on both sides starting at one-quarter of the shell length. Concentric growth lines dense and even over the whole shell. One or two stronger growth lines common near the anterior margin. Endopunctate shell.

Ventral interior. Strong teeth supported by a pair of subparallel, thick and short dental plates. Poorly impressed cordate muscle field about 30% of the length and width; slightly elevated central adductor scars not enclosed by diductor scars anteriorly. Strong crenulations near the margins of both valves about one-quarter of the length, which form broad, flat ridges separated by narrow deep grooves.

Dorsal interior. Strong and erect cardinal process limited to the posterior part of the notothyrial cavity, well-developed myophore fissured centrally. Robust brachiophores triangular at their bases and highly projecting mainly ventrally and slightly anteriorly; short and slightly divergent stout fulcral plates variably developed (strong in Pl. 2, fig. 10). No apparent notothyrial platform, but weak elevation of notothyrial cavity often developed. Well impressed rectangular muscle field just in front of the cardinalia, extending to more than 60% of the length and about 40% of the width, with low and wide bounding ridges and myophragm; two pairs of adductor scars, with the anterior pair of scars larger than the posterior pair. Low and wide median ridge extending to the anterior margin.

MEASUREMENTS

	L	W	L/W	L_1	L_2	W_1	W_2
BB37703, dorsal valve	5.2	5.8	0.89	0.9	–	1.3	–
BB37731, dorsal valve	5.4	6.3	0.86	1.4	3.1	2.0	2.5
BB37736, ventral valve	2.4	2.7	0.89	0.8	–	0.7	–
BB37738, dorsal valve	4.8	6.4	0.75	1.0	3.4	1.9	2.7

DISCUSSION. Bancroft (1928: 55) established *Onniella* for small dalmanellids with a transverse shell, small beaks, dorsal sulcus and no ventral pallial markings. Later (Bancroft, 1945: 211), he further summarized the main and distinguishing characters of *Onniella* as a small dalmanellid with *Resserella*-like crural plates, unequal-sized dorsal muscle scars, feebly-developed ventral muscle field, and without apparent pallial markings. According to Williams & Wright's (1963) detailed revision, *Dalmanella*, externally somewhat close to *Onniella*, differs from the latter in having small fulcral plates, convergent brachiophore supports, comparatively smaller dorsal muscle scars and a more elongate ventral muscle field. Hurst (1979) has discussed and redefined the various species of *Onniella* from the type Caradoc area of Shropshire, including *O. broeggeri* Bancroft, the type species. According to his convincing discussion, the differentiation of species within *Onniella* should be on ribbing and some aspects of the interiors, especially the shape of the ventral muscle field, rather than only on their ribbing patterns as Bancroft believed. The present material from Burma lacks fulcral plates in most specimens, has slightly divergent brachiophore supports, the ventral adductor scars are not enclosed by diductor scars and has rectangular dorsal muscle fields with larger anterior pair of scars; it is therefore assigned to *Onniella*.

All the specimens identified as *Orthis (Dalmanella?) chaungzonensis* by Reed (1906: 61, pl. 4, figs 7–14) are from the Naungkangyi Group at Chaungzon, Northern Shan States, and have no essential differences from our material except for the equal-sized pairs of dorsal adductor scars shown in his figure 9, plate 4, which may have been overemphasised in Reed's drawing. The two exteriors identified as *Orthis (Dalmanella) testudinaria* by Reed (1906: 60, pl. 4, figs 25–26), from the same locality and horizon as *chaungzonensis*, have the same ribbing as the latter. *Orthis (Dalmanella) testudinaria shanensis* (Reed, 1915: 9, pl. 2, figs 6–11), from the Hwe Mawng Formation (equivalent to the Upper Naungkangyi Group) at Hkawnhkok, Northern Shan States, also has the same characters as *chaungzonensis*, except for two ventral interiors (Reed, 1915: pl. 2, figs 8, 11) which may be attributable to *Dalmanella* rather than *Onniella*, because the general shape of the ventral muscle field and the adductor and diductor scars are identical to that of the real *D. testudinaria* from the Baltic.

The *Orthis (Dalmanella) elegantula* of Reed (1906: 60, pl. 4, figs 23–24) was based on two distorted specimens from the Naungkangyi Group at Taungkyun, Northern Shan States, and differs from *chaungzonensis* in shell outline, ribbing and cardinalia but cannot be identified with certainty here. *Orthis (Dalmanella) sinchaungensis* (Reed 1936: 28, pl. 2, figs 12–15a) was named from the rocks corresponding to the Naungkangyi Group at Taungbu, Southern Shan States, and can be distinguished from *chaungzonensis* by much denser costellae, different ribbing style and a larger dorsal muscle field consisting of two pairs of equal-sized adductor scars, and may be a draboviid. The type species of *Onniella*, *O. broeggeri* (Bancroft 1928: 56, pl. 2, figs 1–5) from the Onny Shale Formation of Shropshire, differs from *chaungzonensis* in having coarser costellae and a smaller dorsal muscle field.

Superfamily **CLITAMBONITOIDEA** Winchell & Schuchert, 1893
Family **CLITAMBONITIDAE** Winchell & Schuchert, 1893

Indet. **clitambonitid** Pl. 2, figs 11–12

MATERIAL AND LOCALITY. Four ventral internal and two external moulds from the Naungkangyi Group at Kunkaw (Locality YA40) in the Kyaukme-Longtawkno area, Northern Shan States.

DESCRIPTION. Transverse elliptical shell 5.1–10.2mm long and 7.0–13.8mm wide with length/width ratio 0.73–0.92. Variably convex ventral valve with a shallow and narrow sulcus originating in front of the umbo; apsacline interarea with a large and open delthyrium. Maximum width along the straight hinge line or slightly in front of it. Ornament of multicostellae, 3–4 per mm near the anterior margin. Teeth small; short and shallow spondylium supported by a weak median septum.

DISCUSSION. One of the ventral internal moulds is clearly a clitambonitid, based on the spondylium supported by the short median septum, but it is uncertain whether or not a pseudodeltidium or chilidium is present and thus to which subfamily it should be attributed. The *Clitambonites* cf. *squamata* Pahlen recognised by Reed (1906: 66, pl. 5, fig. 14), from the Naungkangyi Group at Kunlein, Northern Shan States, and the *Clitambonites* cf. *ascendens* Pander identified by Reed (1936: 31, pl. 3, fig. 14), from rocks corresponding to the Naungkangyi Group at Nam Wabya, Southern Shan States, are both based on single specimens which are very

similar to each other, as Reed himself recognised, and can probably be reassigned to *Porambonites* (see below). The ventral exterior identified by Reed (1906: 65, pl. 5, figs 13, 13a) as *Clitambonites* cf. *pyron* (Eichwald), also from the Naungkangyi Group at Sedaw (about 15 km northwest of Kyaukme), Northern Shan States, cannot be revised here owing to lack of material; it may or may not be a clitambonitoid.

Superfamily **PLECTAMBONITOIDEA** Jones, 1928
Family **LEPTELLINIDAE** Ulrich & Cooper, 1936
Subfamily **LEPTELLININAE** Ulrich & Cooper, 1936

Genus *LEPTELLINA (LEPTELLINA)* Ulrich & Cooper, 1936

Leptellina (Leptellina) minor sp. nov.
Pl. 2, figs 13–14; Pl. 3, figs 1–5

1936 *Leptelloidea (Leangella?)* cf. *derfelensis* Jones; Reed: 43, pl. 4, figs 24–25.
1936 *Leptelloidea (Leangella)* cf. *sholeshookensis* Jones; Reed: 43, pl. 4, fig. 28.

HOLOTYPE. BC 52418 (Pl. 3, fig. 2), from the equivalent of the Upper Naungkangyi Group at Linwe (AM78), Southern Shan States, longitude 96°33'E, latitude 21°14'N.

MATERIAL AND LOCALITIES. 107 specimens: 10 dorsal valves, 23 dorsal internal and 14 external moulds, four ventral valves, 33 ventral internal and 13 external moulds from the equivalents of the Upper Naungkangyi Group at Linwe (Localities AM77, AM78); moulds of two ventral interiors and one ventral exterior and counterpart interior from the Bryozoan Sandstone Formation (equivalent to the Upper Naungkangyi Group) in the Neyaungga-Ye-ngan area (Localities BA479, BA490); both in the Southern Shan States. Four ventral internal and two external moulds from the Li-lu Formation (equivalent to the Upper Naungkangyi Group) at Ta-Pangtawng (about 10 km east of Longtawkno, Locality YA454.1), Northern Shan States.

DESCRIPTION. *Exterior.* Small semicircular shell 3.0–6.3mm long and 3.4–8.4mm wide, with length/width ratio 0.66–0.88. Lateral profile strongly concavo-convex, dorsal valve often dorsally geniculate at about 60% of length, strongly convex ventral valve particularly medially. Cardinal extremities acute to nearly rectangular; maximum width along the hinge line. Large, flat and apsacline ventral interarea; posterior half of the delthyrium covered by well-developed arched pseudodeltidium (Pl. 3, fig. 1a). Smaller anacline dorsal interarea; open notothyrium mostly occupied by cardinal process lobes. Parvicostellate ornamentat with 4–5 finer costellae between each pair of coarser ones. No growth lines observed.

Ventral interior. Small teeth with variably developed dental plates weak or absent and extending first subparallel and then medially to enclose the muscle field. Delthyrial cavity very deep. Rectangular or transversely elliptical muscle field elevated from the shell floor, 17–27% of the length and 21–34% of the width; triangular median adductor scars often more elevated than the lateral diductor scars. Vascular markings lemniscate; a pair of strong vascular media originate from the antero-lateral ends of muscle field, extending forward subparallel and branching at about two-thirds of the length; a pair of very weak vascular spondylaria originate laterally from the muscle field, extending to the shell lateral margin with few branches.

Dorsal interior. Small transverse cardinalia 16–21% of the length and 28–31% of the width; strong median cardinal process lobe projecting posteriorly and ventrally and continuous with the low and wide myophragm anteriorly; small lateral pair of lobes variably developed, sometimes absent; socket ridges connected with cardinal process medially and extending laterally subparallel to the hinge line, with two strong ventrally projecting lateral ends; sockets transverse and elliptical. Poorly-impressed circular muscle field just in front of the cardinalia, antero-medial pair of adductor scars slightly larger than the lateral pair. Thin median septum starting from the posterior end of the inner adductor scars, becoming higher anteriorly and reaching its acme at the junction with the platform at the strongest valve convexity. Weakly-elevated platform composed of a series of continual or continuous tubercles, not connected with hinge line posteriorly. Lemniscate vascular markings with a pair of vascular media originating from the anterior ends of inner adductor scars.

MEASUREMENTS

	L	W	L/W	L_1	L_1/L	W_1	W_1/W
BB37590, dorsal valve	5.2	7.8	0.67	1.1	0.21	2.2	0.28
BB37625, dorsal valve	5.6	7.5	0.75	0.9	0.16	2.1	0.28
BB37635, ventral valve	4.6	6.1	0.75	1.2	0.26	2.1	0.34
BB37647, dorsal valve	4.4	5.8	0.76	0.8	0.18	1.8	0.31
BB37652, ventral valve	4.0	6.1	0.66	0.9	0.23	1.5	0.25
BB37742, ventral valve	3.0	3.4	0.88	0.5	0.17	0.8	0.24
BB37755, ventral valve	6.3	8.4	0.75	1.7	0.27	1.8	0.21

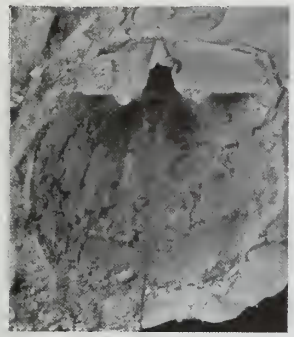
DISCUSSION. This species is the most abundant component of our fauna. Reed (1936: 43) identified a probably identical ventral interior as *Leptelloidea (Leangella)* cf. *sholeshookensis* Jones from rocks corresponding to the Naungkangyi Group at Taunggyi in the Southern Shan States. The true *Leptelloidea sholeshookensis* (Jones 1928: 488, pl. 15, fig. 19) has an undercut cardinal process and well-developed bema and platform, and has been reassigned to *Leangella (Leangella)* by Cocks & Rong (1989: 116). Reed also identified other specimens as *Leptelloidea (Leangella?)* cf. *derfelensis* Jones, but again that Welsh species has been reassigned to *Leangella (Leptestiina)* by Cocks & Rong (1989: 116). Reed illustrated no dorsal valves. Thus, with our more complete material than Reed, we can erect the new species *minor*, which we assign to *Leptellina (Leptellina)*. It differs from the type species *L. tennesseensis* (named by Ulrich & Cooper in 1936: 626, but illustrated by Ulrich & Cooper in 1938: 192, pl. 39, figs 1–2, 4–5), from the Lenoir Formation

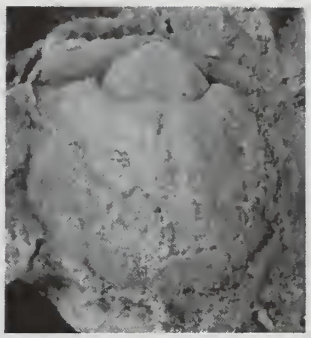
PLATE 3

Figs 1–5 *Leptellina (Leptellina) minor* sp. nov. **1–4**, Linwe, Locality AM78. **1a, 1b**, BB 37623, latex cast and internal mould of ventral interior showing poorly developed pseudodeltidium and small teeth, × 5. **2a, 2b**, BC 52418, Holotype, latex cast and internal mould of dorsal interior with another dorsal interior at the top left (BB 37590), × 5. **3**, BB37659, dorsal internal mould, × 4. **4**, BB 37629, latex cast of dorsal exterior, showing dorsal interarea and chilidium, × 4. **5**, BC 52417, Ta-Pangtawng, Locality YA454.1, ventral internal mould, × 6.

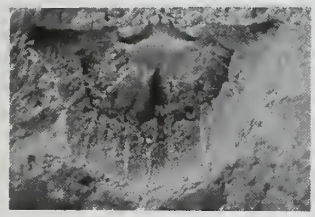
Figs 6–9 *Bekkerella subcrateroides* (Reed). **6–8**, Kunkaw. **6**, BB 37768, Locality YA50.1, latex cast of dorsal exterior, × 4. **7a–d**, BB 37759, Locality YA256, latex cast of exterior, internal mould, latex cast of interior and posterior view of internal mould of ventral valve together with a dorsal external mould (BC 52410), × 4. **8a, 8b**, BB 37774, Locality YA315.1, dorsal internal mould, and latex cast, × 3. **9a, 9b**, BB 37750, Namyun, latex cast and internal mould of dorsal interior, × 2.

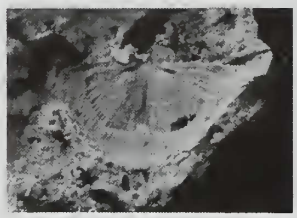
Fig. 10 *Ishimia subdeltoidea* (Reed). B 29672, Tawmawgon, latex cast and internal mould of dorsal interior, × 2.

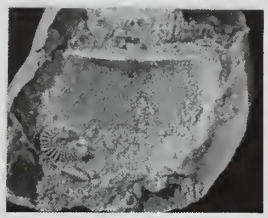

1a

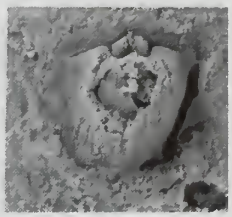

1b

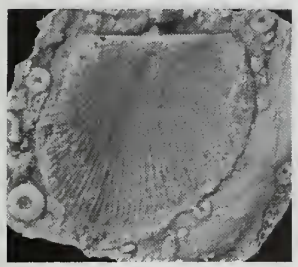

2a

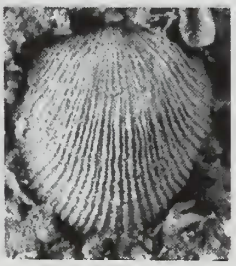

2b


3

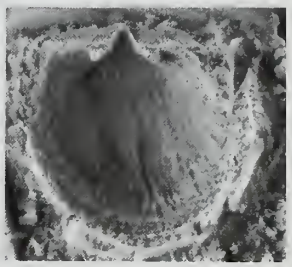

4


5


6


7a


7b


7c


8a

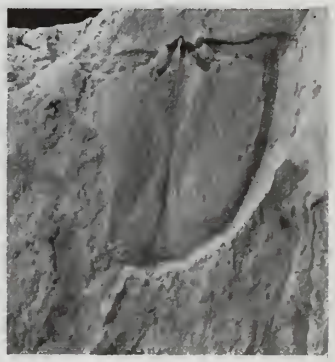

8b


9a


9b


7d


10a


10b

(Llandeilo) at Friendsville in Tennessee, U. S. A., in having a smaller shell, less numerous parvicostellae and less acute cardinal extremities. The *Leptellina sinensis* of Xu, Rong & Liu (1974: 152, pl. 66, figs 13, 17–18) from the Shihtzupu Formation (early Caradoc) of Guizhou, South China, differs from *minor* in having a much larger shell, comparatively larger dorsal interarea, denser parvicostellae, less well-developed ventral muscle field and dorsal platform.

The specimen identified by Reed (1915: 13, pl. 3, fig. 3) as *Plectambonites* cf. *llandeiloensis* (Davidson) from the Li-lu Formation (equivalent to the Upper Naungkangyi Group) at Li-lu, Northern Shan States, has an undercut cardinal process, strongly elevated bema and well-developed platform, and is here reassigned to *Leangella (Leangella)* sp. Davidson's *llandeiloensis* itself has been reassigned to *Leptellina* by Williams (1962: 164). A ventral valve, the holotype of Reed's new species *Leptelloidea (Leangella?) lamellata* (1936: 44, pl. 4, figs 22–23, 23a), from rocks corresponding to the Naungkangyi Group at Taunggyi of the Southern Shan States, is similar to *L. (L.) minor* in shell outline and convexity, but differs from the latter in having fewer larger costellae, a more deeply impressed and more elongate muscle field and a pair of strong vascular dentalia. Since only a single ventral valve was illustrated, we consider *lamellata* as generically indeterminable. Comparably, *Leptelloidea yeosinensis* was described from Ye-o-sin, Southern Shan States, by Reed (1932: 196, pl. 3, figs 3–6) and the well-illustrated dorsal valves indicate that it is a leptellinid, but differing from *L. (L.) minor* in its lack of thin dorsal median septum anteriorly and the presence of a bema. However, its detailed generic position is not determinable.

Several variations are observed in our specimens of *L. (L.) minor*, including: (1) ventral convexity; most of the ventral valves are very convex but some are more gentle; (2) geniculation; over 80% of the dorsal valves have marked geniculation, while the remaining minority have much weaker or even absent geniculation; (3) ventral muscle field; the dental plates are usually weak and enclose the elevated muscle field in which the medial adductor scars are higher than the lateral diductor scars. Sometimes the small teeth have no supports and the slightly elevated diductor and adductor scars are indistinguishable from each other; (4) cardinal process; the central lobe is always well-developed, while the lateral lobes are often absent; (5) platform; the presence of a platform is one of the main characters of this genus, but it is variably developed and elevated in *L. (L.) minor*, and occasionally it is even composed merely of a series of discontinuous tubercles.

Genus *BEKKERELLA* Reed, 1936

Bekkerella subcrateroides (Reed, 1906) Pl. 3, figs 6–9

1906 *Orthis subcrateroides* Reed: 63, pl. 4, figs 27–33.
1915 *Orthis subcrateroides* Reed; Reed: 12.
1936 *Rafinesquina (Bekkerella) gentilis* Reed: 38, pl. 4, fig. 14.

MATERIAL AND LOCALITIES. Nine dorsal internal, eight external, 10 ventral internal and four external moulds from the Naungkangyi Group at Kunkaw (Localities YA42, YA50.1, YA256 and YA315.1); one dorsal internal, two external and four ventral external moulds from the Li-lu Formation (equivalent to the Upper Naungkangyi Group) at Li-lu (about 11 km southeast of Longtawkno, Locality YA630); one ventral valve (internal and external moulds) from the Taungkyun Formation (equivalent to the Lower Naungkangyi Group) at Li-lu (Locality YA139); one ventral internal mould at Chaungzon, and two dorsal internal moulds at Namyun, both from the Naungkangyi Group; all in the Northern Shan States.

DESCRIPTION. *Exterior*. Subquadrate to subcircular shell 6.9–18.7mm long and 7.7–23.8mm wide with length/width ratio 0.71–1.0. Lateral profile concavo-convex; dorsal valve slightly concave medio-posteriorly with a small anterior geniculation; strongly convex ventral valve particularly medially. Cardinal extremities round, maximum width at about mid-length. Large flat apsacline ventral interarea, small beak, only posterior one-third covered by small arched pseudodeltidium; smaller hypercline dorsal interarea, notothyrium completely occupied by cardinal process. Multibranching costellae, equal in size, near the anterior margin, about 4 per mm. Growth lines closely spaced, 12 per mm longitudinally.

Ventral interior. Stout triangular teeth without supports. Delthyrial cavity with some secondary shell accumulation. Poorly-impressed muscle field about one-third to two-fifths of shell length and width, without apparent surrounding ridges, adductor and diductor scars indistinguishable from each other. Variably-developed subperipheral ridge extending posteriorly towards the hinge line and then medially to the teeth lateral sides parallel to the hinge line. Vascular markings saccate, a pair of vascular media originating in front of the muscle field and extending forward with several branches.

Dorsal interior. Small cardinalia 12–23% valve length and 21–32% valve width; cardinal process usually simple but occasionally trifid, median lobe elongate and strongly projecting ventrally and posteriorly; thick and straight socket ridges divergent at 60–100°, extending posteriorly and connecting with the lateral lobes of cardinal process; the whole notothyrial cavity highly elevated and thickened by secondary shell; large deep sockets open anterolaterally. Slightly elevated quadrate muscle field with distinctive bounding ridges, posterior pair of scars a little larger than the anterior pair; thick and strong myophragm originating from the notothyrial platform, becoming thinner and higher anteriorly, with its acme just in front of the muscle field, merging into the platform. Variably-developed quadrate platform slightly undercut and extending posteriorly to the hinge line. All the area outside the platform geniculate dorsally.

MEASUREMENTS

	L	W	L/W	L1	L1/L	W1	W1/W	∝
BC52182, dorsal valve	6.9	7.7	0.90	1.3	0.19	2.1	0.27	75°
BB37750, dorsal valve	11.5	16.1	0.71	2.6	0.23	3.6	0.22	60°
BB37757, dorsal valve	18.7	23.8	0.79	2.3	0.12	5.0	0.21	100°
BB37759, ventral valve	8.7	8.7	1.0	2.9	0.33	2.9	0.33	–
BB37774, dorsal valve	8.6	10.4	0.83	1.6	0.19	3.3	0.32	89°
SMA3128, ventral valve	11.9	12.3	0.97	5.2	0.44	5.0	0.41	–

DISCUSSION. *Bekkerella* appears endemic to Burma and is characterized by undifferentiated fine radial ornamentation, a slightly elevated and distinctive dorsal muscle field, a strong median septum and a quadrate platform. *Acculina* and *Shlyginia*, also common in Caradoc times, are similar to *Bekkerella* in dorsal interior, but they both have parvicostellate ornamentation, and in addition *Acculina* has a resupinate profile, well-developed pseudodeltidium and a bilobed ventral muscle field with extended dental plates as bounding ridges (Cocks & Rong 1989: 103). *Shlyginia* has a much larger ventral muscle field within which adductor scars are enclosed by diductor scars, and a small cardinal process seldom projecting posterior to the hinge line.

Reed (1936: 38) erected the subgenus *Bekkerella* within *Rafinesquina*, with *Orthis subcrateroides* Reed (1906) from the Naungkangyi Group at Chaungzon in the Northern Shan States as its type species. The single ventral interior which he illustrated from the Southern Shan States in 1936 has a muscle field which was overemphasised in the drawing (Reed 1936, pl. 4, fig. 14), since none of

Reed's illustrated ventral valve muscle fields of *subcrateroides* is so elongate and divergent. All our present specimens are also from the Naungkangyi Group from several localities in the Northern Shan States and are identical to *subcrateroides*. Some variations observed in this material are: (1) dorsal concavity; most dorsal valves are slightly concave or nearly flat medial-posteriorly, with a small but strong geniculation anterior to the platform, but there are a few individuals with an evenly concave dorsal valve and no geniculation (e.g. Pl. 3, fig. 6); (2) cardinal process; lateral lobes are usually absent, but they are present in a few specimens and continuous antero-laterally with the straight socket ridges; (3) platform; most dorsal valves have a well-developed and slightly undercut platform, but a few specimens, particularly juveniles, have a very weak platform.

Subfamily **PALAEOSTROPHOMENINAE** Cocks & Rong, 1989

Genus ***ISHIMIA*** Nikitin, 1974

Ishimia subdeltoidea (Reed, 1906)

Pl. 3, fig. 10; Pl. 4, figs 1–7

1906 *Rafinesquina subdeltoidea* Reed: 52–53, pl. 5, figs 1–8.
1936 *Rafinesquina (Kjaerina)* cf. *felix* Reed; Reed: 37, pl. 4, fig. 1.

MATERIAL AND LOCALITIES. Eight dorsal internal, six external, eight ventral internal and three external moulds at Tawmawgon (about 30 km north of Kyaukme); three dorsal internal, one ventral internal and one external moulds at Kunkaw (Localities YA45.1, YA315), both from the Naungkangyi Group; two dorsal internal and external moulds from the Li-lu Formation (equivalent to the Upper Naungkangyi Group) at Ta-Pangtawng (about 10 km east of Longtawkno); all in the Northern Shan States. Two dorsal internal moulds from the equivalents of the Upper Naungkangyi Group at Linwe (Locality AM77), Southern Shan States.

TYPES. Lectotype, here selected, the original of Reed 1906, pl. 5, fig. 4, a dorsal internal mould from Tawmawgon, Northern Shan States. Indian Geological Survey Museum, Calcutta.

DESCRIPTION. *Exterior.* Lateral profile concavo-convex; dorsal valve flat or slightly concave medial-posteriorly, with variably developed dorsal geniculation, some strong and nearly perpendicular; ventral valve convex, with convexity increasing anterior to the dorsal valve geniculation. Cardinal extremities usually acute, maximum width along the hinge line. Large, apsacline, flat ventral interarea; ventral beak slightly curved; delthyrium only about one-quarter covered by pseudodeltidium. Smaller hypercline dorsal interarea with a well-developed arched chilidium. Ornament of coarse parvicostellae, unevenly distributed, about 3–4 per mm near the margin; only 1–2 finer costellae between two coarser ones. Growth lines well-preserved on the geniculation, 8–9 per mm; several concentric comae often present postero-laterally.

Ventral interior. Small triangular or wedge-like teeth without supports. Weakly-impressed muscle field with no bounding ridges; antero-median pair of diductor scars much larger than the postero-lateral pair and with a short and weak myophragm, small adductor scars in the posterior centre of the muscle field. Vascular markings leminiscate; vascular media originating from the inner sides of the anterior end of the muscle field, and vascular myaria starting between the two pairs of diductor scars.

Dorsal interior. Cardinalia about one-fourth shell length and width; very high, thin plate-like cardinal process median lobe projecting ventrally, lateral lobes often absent; straight socket ridges separated from the median lobe, divergent at about 75–100°, extending antero-laterally far beyond the sockets, showing thin plate-like crura; the cardinal area elevated by the deposition of secondary shell; deep and narrow or round sockets open or with thick and low bounding ridges antero-laterally. Well-impressed elongate oval muscle field including a smaller anterior pair and larger posterior pair of adductor scars, low bounding ridges often absent; thick and high myophragm originating from the notothyrial platform and extending forward to become thinner and higher, reaching its acme at the anterior end of the muscle field and continuous anteriorly with the thin median septum which ends before or merges into the platform. Quadrate platform slightly elevated, extending posteriorly to the hinge line. The geniculation is immediately anterior of the platform.

DISCUSSION. Most of our present material was collected from Reed's type locality of *subdeltoidea*, Tawmawgon in the Northern Shan States, and is identical to Reed's illustrated specimens. The distorted dorsal interior, from rocks corresponding to the Naungkangyi Group at Hpongyi Kyaung in the Southern Shan States and identified by Reed as *Rafinesquina (Kjaerina)* cf. *felix*, is basically similar to some of our specimens and is thus assigned to *subdeltoidea* here. The true *felix* of Reed (1917) is a quite different strophomenoid from the middle Ashgill of Girvan, Scotland (Cocks 1978). When Nikitin (1974: 59) established *Ishimia* from the Middle Ordovician of Central Kazakhstan, he recognised four species, *I. humilis* (Nikitin 1974: 63; pl. 6, figs 1–3), from the Yerkebidaik Horizon (middle Caradoc) of Chingiz in Central Kazakhstan, lacks geniculation, but otherwise is the most similar to *subdeltoidea*, although it differs in having finer costellae and a more elongate bilobed ventral muscle field. The type species, *I. ishimensis* (Nikitin 1974: 61, pl. 5, figs 10–16) from the Karakan Horizon (late Llanvirn) of Kupriyanovka in Central Kazakhstan, can be distinguished in having finer and more differentiated costellae, larger ventral adductor scars, and stronger dorsal bounding ridges, median septum and platform.

Some variations within the dorsal interior observed from our material of *I. subdeltoidea* are: (1) cardinal process; most specimens have only a strong single cardinal process lobe, but a few develop a pair of small lateral lobes, making the cardinal process trifid and hence the genus is appropriately placed within the Leptellinidae; (2) sockets; the antero-lateral sides are sometimes open, while a few specimens have low bounding ridges; (3) median septum; this usually ends before the platform, but in a few specimens it merges anteriorly with the platform.

Family **SOWERBYELLIDAE** Öpik, 1930
Subfamily **PTYCHOGLYPTINAE** Cooper, 1956

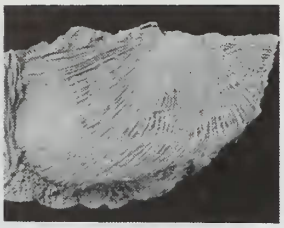
Genus ***PTYCHOGLYPTUS*** Willard, 1928

Ptychoglyptus? shanensis Reed, 1932

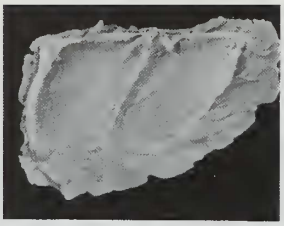
1932 *Ptychoglyptus shanensis* Reed: 195, pl. 3, fig. 15.
1936 *Ptychoglyptus shanensis* Reed; Reed: 37.

DISCUSSION. Reed (1932) named the species *Ptychoglyptus shanensis* from rocks corresponding to the Naungkangyi Group at Ye-o-sin in the Southern Shan States, on the basis of a single specimen showing distinctive zigzag rugae interrupted by costae. Although it may be a *Ptychoglyptus*, this is not certain until interiors are discovered, since very similar ornament can be found on some strophomenoid rafinesquinds such as *Pentlandina*. Thus the generic attribution is queried here.

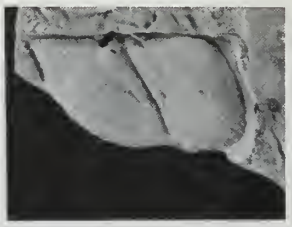
1



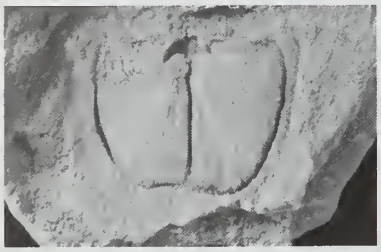
2



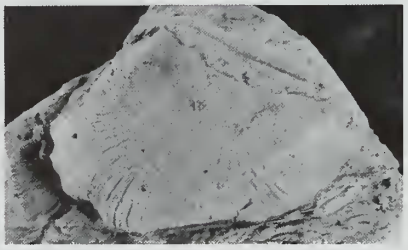
3a



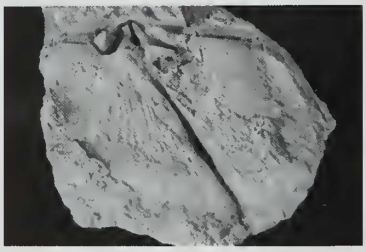
3b



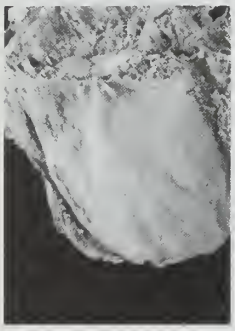
4



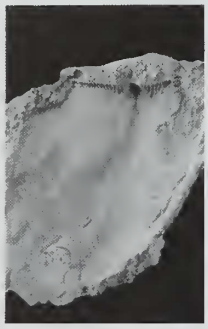
5



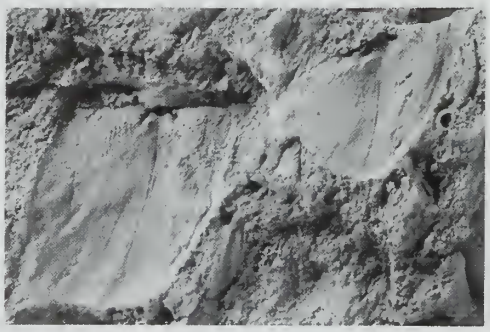
6



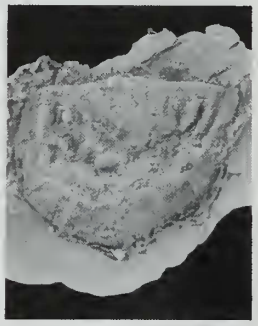
7a



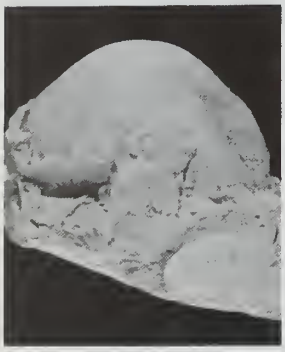
7b



7c

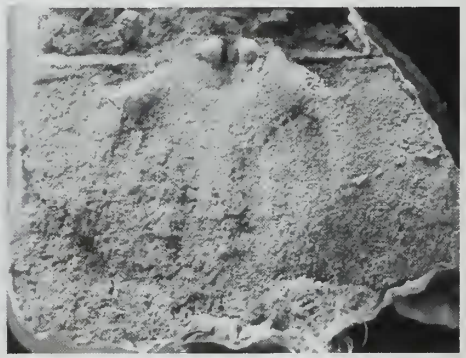


8

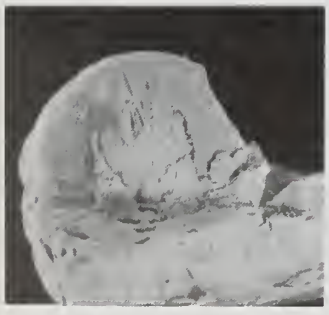


9a

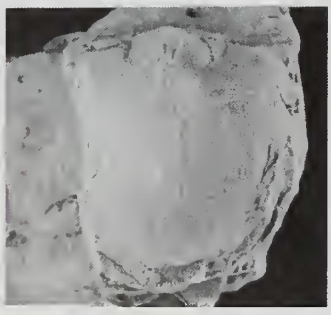
10



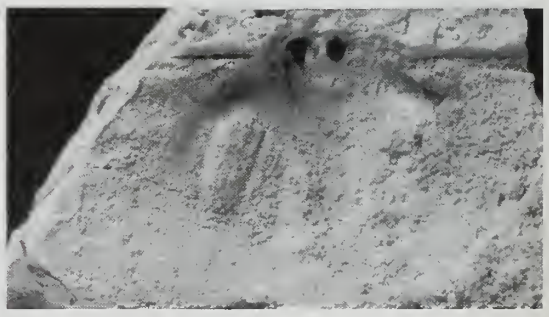
11a



9b



9c



11b

Superfamily **STROPHOMENOIDEA** King, 1846
Family **STROPHOMENIDAE** King, 1846
Subfamily **FURCITELLINAE** Williams, *in* Williams *et al.*, 1965

Genus ***BELLIMURINA (BELLIMURINA)*** Cooper, 1956

Bellimurina (Bellimurina)? sp. Pl. 4, fig. 8

DISCUSSION. One ventral valve (internal and external moulds, BB37585) from the equivalents of the Upper Naungkangyi Group at Linwe, Southern Shan States, has some characters typical of *Bellimurina (Bellimurina)*, such as a convex ventral valve with dorsal geniculation, a surface covered by zigzag rugae, and short and divergent dental plates (Cooper 1956: 854); but lack of material, especially dorsal valves, still makes our identification uncertain. *Bellimurina rudis* Xu, Rong & Liu (1974: 153, pl. 66, figs 14–16), from the Shihtzupu Formation (early Caradoc) of northern Guizhou, South China, is larger in shell size, has much stronger zigzag rugae and more impressed ventral muscle field with distinctive surrounding ridges. It is therefore not conspecific with this Burmese specimen.

Family **RAFINESQUINIDAE** Schuchert, 1893
Subfamily **RAFINESQUININAE** Schuchert, 1893

Genus ***DIRAFINESQUINA*** gen. nov.

TYPE SPECIES. *Dirafinesquina globosa* sp. nov.

DIAGNOSIS. Family characteristics of Rafinesquinidae. Like *Rafinesquina* but with ventral valve bounding ridges surrounding a suboval muscle field; cardinal process lobes weaker and erect rather than anteriorly directed and with socket ridges better developed.

DESCRIPTION. As for *Dirafinesquina globosa* below.

DISCUSSION. The true *Rafinesquina*, from the Caradoc-Ashgill of North America, has been revised and reillustrated by Rong & Cocks (1994). Reed (1906, 1936) attributed various Burmese specimens to species of *Rafinesquina* (see specific discussion below), but we consider that all the specimens in our collections and some of Reed's material from the Shan States may be grouped together within a single species, erected below as *Dirafinesquina globosa*.

The new genus can be firmly placed within the subfamily Rafinesquininae and the family Rafinesquinidae by its cardinalia, normal convexity and lack of rugae. There are ten other members of the subfamily. Of those of comparable age, *Rafinesquina* itself appears the closest, but with the differences mentioned in the diagnosis above. *Dirafinesquina* differs from *Colaptomena* and *Hedstroemina* in the large chilidium and pseudodeltidium and from the former in the lack of dorsal median septum; and from the latter in the lack of strong dental plates. It differs from *Kjaerina* in the suboval rather than triangular ventral muscle field and larger chilidium, and from *Kjerulfina* in its lack of ventral geniculation and rugae. *Megamyonia* has distinctive ventral trans-muscle septa and other very different characters. *Odoratus* has ventral geniculation and lacks ventral muscle bounding ridges. *Rhipidomena* is resupinate and has dorsal trans-muscle ridges.

Dirafinesquina globosa sp. nov.
Pl. 4, figs 9–11; Pl. 5, figs 1–3, 5

?1936 *Rafinesquina* cf. *alternata* Conrad; Reed: 69, pl. 3, fig. 6.
1936 *Rafinesquina* cf. *semiglobosina* Davidson; Reed: 70, pl. 3, fig. 7.

HOLOTYPE. BB37593 (Pl. 4, fig. 11), from the equivalents of the Upper Naungkangyi Group at Linwe (Locality AM78), Southern Shan States, longitude 96°33'E, latitude 21°14'N.

MATERIAL AND LOCALITIES. 31 specimens: three dorsal internal and two external, 20 ventral internal and six external moulds from the equivalents of the Upper Naungkangyi Group at Linwe (Locality AM78) and Loke-pyin (about 14 km southeast of Ye-ngan, Locality AM106), Southern Shan States.

DESCRIPTION. *Exterior*. Large, subcircular shell more than 20mm long and wide with length/width ratio about 1.0. Lateral profile concavo-convex; dorsal valve evenly and gently concave; ventral valve gently convex posteriorly, with variable but sometimes sharply increasing convexity dorsally at about mid-length. Cardinal extremities round or rectangular, maximum width along the hinge line or a little anterior to it. Large flat apsacline ventral interarea with an arched pseudodeltidium, narrower anacline dorsal interarea with a much larger and more arched chilidium. Ornament of multibranching parvicostellae, 3–5 finer costellae between two coarser ones. No growth lines observed.

Ventral interior. Small rod-like or triangular teeth supported by weak dental plates which extend forward as muscle bounding ridges. Well-impressed, elongated oval muscle field 43–55% valve length and 37–39% valve width; a pair of long, kidney-shaped adductor scars slightly elevated and open anteriorly; diductor scars narrowing anteriorly, but longer than the adductor scars. Saccate vascular markings with a pair of vascular media originating from the anterior ends of adductor scars.

Dorsal interior. Relatively small cardinalia (Type B of Rong & Cocks 1994) with a variably developed, sometimes ponderous, cardinal process; triangular, sessile and discrete lobes including a plate-like shaft and a swollen myophore, and project ventrally and anteriorly; low, short, straight and variably thick socket ridges separated from the cardinal process; notothyrial cavity elevated; small shallow sockets open antero-laterally. Well-impressed circular muscle field, particularly posteriorly; low and wide myophragm starting from the notothyrial platform and narrowing anteriorly. No vascular markings observed.

MEASUREMENTS. Most of our specimens are broken and so only

PLATE 4

Figs 1–7 *Ishimia subdeltoidea* (Reed). Tawmawgon. **1**, BC 52420, ventral internal mould, × 1.5. **2**, SMA 3124, latex cast of ventral exterior, × 1.5. **3a, 3b**, SMA 3127, latex cast and internal mould of dorsal interior, × 1.5. **4**, SMA 3126, dorsal internal mould, × 2. **5**, SMA 3125, dorsal external mould, oblique view showing the dorsal geniculation, × 1.5. **6**, BC 52191, dorsal internal mould showing small curved socket ridges, × 2. **7a–c**, B 29664, latex cast and internal mould of a dorsal valve with another dorsal internal mould to the right, both with weaker platforms, × 1.5.

Fig. 8 *Bellimurina (Bellimurina)*? sp. BB 37585, Linwe, Locality AM78, latex cast of ventral exterior, × 4.

Figs 9–11 *Dirafinesquina globosa* gen. et sp. nov. Linwe, Locality AM78. **9a–c**, BB 37607, lateral, posterior and ventral views of ventral internal mould, × 1.5. **10**, BB 37600, latex cast of dorsal interior showing the cardinalia and muscle field, × 5. **11a, 11b**, BB 37593, Holotype, latex cast and internal mould of dorsal interior, × 5.

three ventral valves are measured here.

	L	W	L/W	L1	L1/L	W1	W1/W
BB37606, ventral valve	23.9	23.7	1.01	13.2	0.55	9.2	0.39
BB37607, ventral valve	23.7	23.6	1.00	10.8	0.46	8.8	0.37
BB37619, ventral valve	20.6	20.5	1.00	8.9	0.43	7.8	0.38

DISCUSSION. A dorsal valve (Reed 1936: 69, pl. 3, fig. 6) was identified as *Rafinesquina* cf. *alternata* Conrad and a ventral valve (Reed 1936: 70, pl. 3, fig. 7) identified as *R.* cf. *semiglobosina* Davidson; both were from the Bawzaing Horizon (equivalent to the Naungkangyi Group) of Sinchaung, Southern Shan States: both are similar to our present material. *R. alternata*, the type species of *Rafinesquina* from the Hudson River Group (Caradoc) at Cincinnati, Ohio, U. S. A., differs from the Burmese material in having a larger shell, much less differentiated but denser costellae, and less impressed ventral muscle field, as well as the generic differences mentioned above. The true *semiglobosina* (*see* Reed 1917: 869, pl. 12, figs 13–20) has cardinalia of Type A and well-developed dorsal transmuscle ridges and has been reassigned to the furcitellid *Dactylogonia* by Williams (1962: 201) and Cocks (1978: 120). So we propose a new species *globosa* for our specimens, in which we provisionally include Reed's two exteriors.

The specimens illustrated as *Rafinesquina imbrex* Pander by Reed (1906: 52, pl. 5, figs 9–12), from the Naungkangyi Group at Tawmawgon in the Northern Shan States, have cardinalia of Type A, well-developed dorsal muscle-bounding ridges and a strong median septum, and so they are within the subfamily Furcitellinae. The dorsal exterior identified as *Rafinesquina* cf. *richardsoni* Reed by Reed (1936: 37, pl. 3, fig. 9), from the rocks corresponding to the Naungkangyi Group at Hpongyi Kyaung in the Southern Shan States, differs from our new species in having a much more transverse shell and denser costellae. Compared with the true *richardsoni* (Reed 1917: 868, pl. 12, figs 11, 11a, 12) from the Whitehouse Group (Caradoc) at Shalloch Mill, Girvan, its ornament is more differentiated and denser, although they are similar in shell outline. Since no internal moulds are available, the specimen has not been reidentified here.

Subfamily **LEPTAENINAE** Hall & Clarke, 1894

Indet. **leptaenines** Pl. 5, fig. 4

DISCUSSION. One exterior (BB37744), from the Li-lu Formation (equivalent to the Upper Naungkangyi Group) at Ta-Pangtawng (about 10 km east of Longtawkno), Northern Shan States, has well-differentiated parvicostellae with 6–8 finer costellae between two coarser ones, evenly populated growth lines 18 per mm, and concentric rugae, and appears to be a leptaenine. Two specimens from the Naungkangyi Group at Ledet and Lebyaungbyan (about 7 km west of Maymyo), Northern Shan States, identified by Reed (1906: 55, pl. 4, figs 39–41) as the new species *Leptaena? ledetensis*, have stronger and fewer coarse costellae which cut through all the concentric rugae, and a distinctive ventral interior, so *ledetensis* should probably be reassigned to some other genus, possibly outside the Rafinesquinidae. Reed (1936) also identified three species of *Leptaena*, all on the basis of single specimens from rocks corresponding to the Naungkangyi Group in the Southern Shan States. The specimen Reed (1936: 33, pl. 3, fig. 3) called *L.* cf. *juvenilis* Öpik has undifferentiated costellae and strong concentric rugae which bend suddenly posteriorly at a sharp re-entrant angle in the valve centre, but the true *juvenilis* from Estonia (Öpik 1930: 173, pl. 11, figs 140–141; pl. 12, figs 142–145) has parvicostellae and concentric rugae not bending in the middle: however, Reed's Burmese specimen might be assigned to *Leptaena (Leptaena)*. The *Leptaena* cf. *richmondensis* Foerste of Reed (1936: 34, pl. 3, fig. 11) is a ventral valve which is different from Foerste's true *richmondensis* (1909: 211, pl. 4, figs 10A, B) from the Waynesville Formation of Madison, Indiana, U.S.A., in having a different shell outline, well-differentiated parvicostellae and less developed concentric rugae. We also assign it to *Leptaena (Leptaena)*, but it is not certain whether or not the various Burmese specimens belong to the same species. *Leptaena spectata* Reed (1936: 34, pl. 3, fig. 12), from the Naungkangyi Group of Taungtala, Southern Shan States, is founded on a single distorted ventral internal mould although it is similar to our specimen in ornamentation; but we cannot properly characterise Reed's species without more material, and thus leave the one or more leptaenine species from the Naungkangyi Group in open nomenclature.

Family **GLYPTOMENIDAE** Williams, *in* Williams *et al.*, 1965
Subfamily **GLYPTOMENINAE** Williams, *in* Williams *et al.*, 1965

Genus *GLYPTOMENA* Cooper, 1956

Glyptomena sp. Pl. 5, fig. 6

DISCUSSION. A single concave dorsal valve (external and internal mould, BB37586), from the equivalents of the Upper Naungkangyi Group at Linwe (Locality AM78), Southern Shan States, has a pair of small, discrete and sessile cardinal process lobes with straight socket ridges fused directly onto their lateral bases, which is typical of *Glyptomena*. Little can be seen on the external and internal moulds except for the cardinalia.

Superfamily **PORAMBONITOIDEA** Davidson, 1853
Family **SYNTROPHOPSIDAE** Ulrich & Cooper, 1936

Indet. **syntrophopsid** Pl. 5, fig. 7

DISCUSSION. One slightly distorted ventral valve (BB37691), from the equivalents of the Upper Naungkangyi Group at Loke-pyin (about 14 km southeast of Ye-ngan, Locality AM106), Southern

PLATE 5

Figs 1–3, 5 *Dirafinesquina globosa* gen. et sp. nov. Linwe, Locality AM78. **1a–d**, BB 37619, latex cast, and anterior, ventral and posterior views of ventral internal mould, × 2. **2a, 2b**, BB 37606, posterior and ventral views of ventral internal mould, × 1.5. **3**, BB 37612, ventral internal mould, × 5. **5**, BB 37604, ventral internal mould, showing the muscle field, × 2.

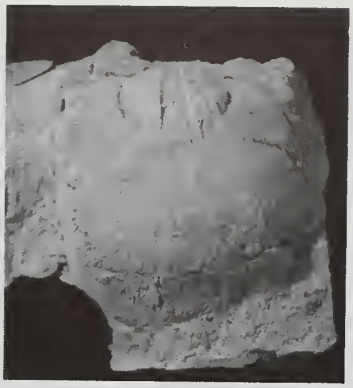
Fig. 4 Indeterminate leptaenind. BB 37744, Ta-Pangtawng, Locality YA454.1, latex cast of dorsal exterior, × 2.

Fig. 6 *Glyptomena* sp. BB 37586, Linwe, Locality AM78, **6a–c**, latex cast and internal mould of dorsal interior, and dorsal external mould, × 3, × 2, × 2.

Fig. 7 Indeterminate syntrophopsid. BB 37691, Loke-pyin, Locality AM106, latex cast and internal mould of ventral interior, × 5, × 10.

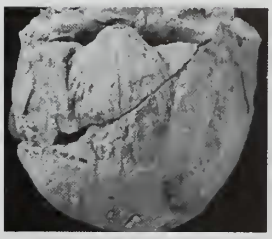
Figs 8–9 *Porambonites* spp. **8**, B 29671, Lebyaungbyan, ventral internal mould, × 1.5. **9a, 9b**, SMA 3133, Sedaw, ventral and dorsal views of conjoined valves, × 1.5.

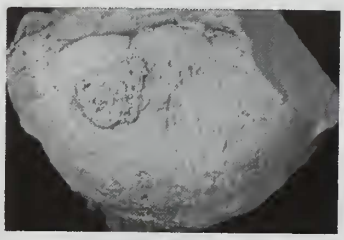

1a


1b

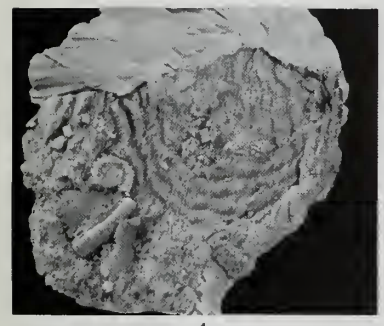

1c

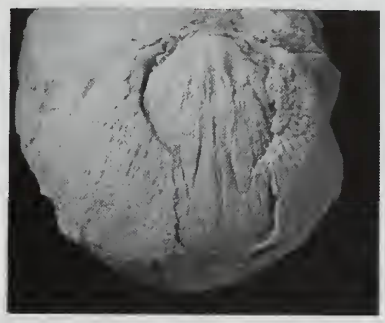

2a

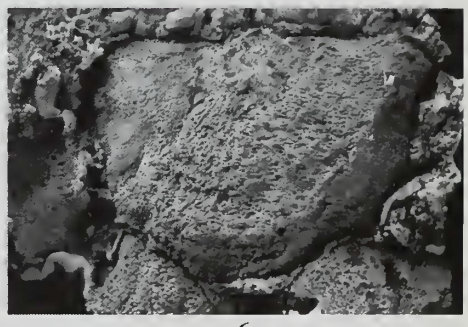

2b

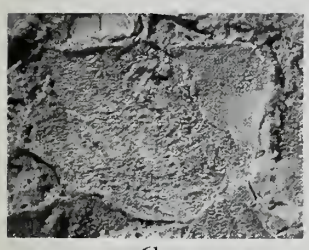

3


1d

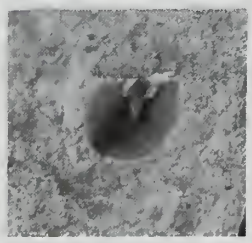

4

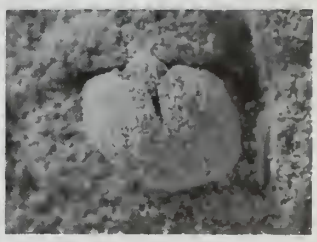

5

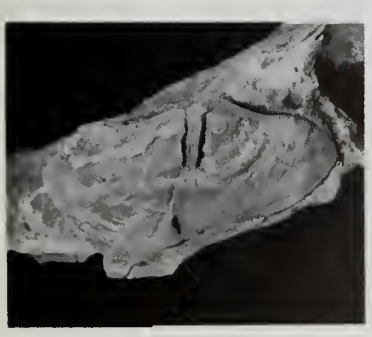

6a

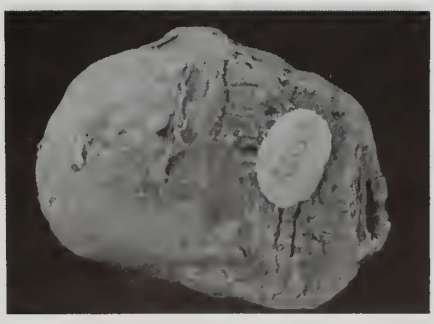

6b

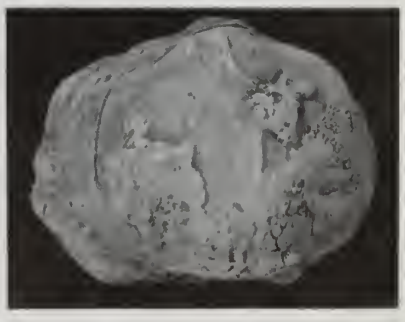

6c


7a


7b


8


9a


9b

Shan States, has a smooth shell, a mostly sessile spondylium and a short median septum originating near the anterior end of the spondylium, all of which are typical of *Syntrophopsis* Ulrich & Cooper (1936: 630). Among the 12 species recognized by Ulrich & Cooper (1938) within *Syntrophopsis*, *S. laevicula* (p. 233, pl. 50, figs 22–28), from the West Spring Creek Formation (late Arenig) of Oklahoma, U. S. A., is most similar to our specimen, but without more material, particularly the dorsal interior, no further identification is possible.

Family **PORAMBONITIDAE** Davidson, 1853

Genus ***PORAMBONITES*** Pander, 1830

Porambonites spp. Pl. 5, figs 8–9

MATERIAL AND LOCALITIES. One individual, SMA 3133, with conjoined valves from Sedaw (about 15 km northwest of Kyaukme) and one ventral internal mould, B 29671, from Lebyaungbyan (about 7 km west of Maymyo), both from the Naungkangyi Group of the Northern Shan States.

DESCRIPTION. Subquadrate dorsi-biconvex shell. Straight hinge line about two-thirds of shell width, round cardinal extremities; maximum width at mid-length. Dorsal fold originating from the umbo; ventral sulcus starting at about mid-length and widening anteriorly to two-thirds shell width. Uniform costellae 4 per mm near the anterior margin. Thin, high and subparallel dental plates to about 40% of shell length; a low transverse ridge connecting their two anterior ends forming a sessile pseudospondylium.

DISCUSSION. Williams *et al.* (1965: H532) accepted *P. intermedius* Pander (1830) as the nominate type species but pointed out that *P. reticulatus* Pander (1830) represents the distinctive characters of this genus. The specimens from Burma have some crucial features of *Porambonites*, i.e., the outline, sulcus and the sessile pseudospondylium in one specimen. The individual illustrated and recognised by Reed (1906: 68, pl. 5, figs 15, 15a, 15b) as *P. intercedens* Pander, from the same locality and horizon as ours, has a globular outline, weaker fold and sulcus, and denser radial ornamentation. *P. sinuatus* Reed (1915: 14, pl. 3, figs 4–5), named on the basis of a ventral valve from the Upper Naungkangyi Group at Mangai of the Northern Shan States, has a much deeper sulcus and a pair of divergent dental plates. Reed (1936) also recognised two species from rocks corresponding to the Naungkangyi Group in the Southern Shan States. *P.* cf. *acutiplicata* Reed from Konleau (Reed 1936: 48, pl. 3, figs 1–2) has a much more transverse shell with comparatively shorter hinge line and deeper sulcus originating from the umbo and might also be referred to *Porambonites* sp. The true *acutiplicata* Reed (1917: 68, pl. 22, figs 10–11) from Girvan, Scotland, is more circular with a longer hinge line. *P.* cf. *wahli* Heinrichson from Ye-o-sin (Reed 1936: 49, pl. 3, fig. 15) has a more circular shell, a weaker fold and much denser costellae, which is very similar to Heinrichson's true *wahli* (1932: 159, pl. 2, figs 1–4) from the Caradoc of Estonia, so Reed's identification is suitable in the absence of more material. Specimens of *P. triquetrus* Xu, Rong & Liu (1974: 153, pl. 66, figs 34–35) from the Shihtzupu Formation (early Caradoc) at Zunyi, Guizhou, South China, are very similar to our material except for their shorter hinge line and weaker fold and sulcus. As mentioned under the indeterminate clitambonitid above, the two specimens illustrated as *Clitambonites* cf. *squamata* by Reed (1906: 66, pl. 5, fig. 14) and *Clitambonites* cf. *ascendens* by Reed (1936: 31, pl. 3, fig. 14) may also represent a species of *Porambonites*, but it appears to be a different species from our illustrated specimens and also from *P. sinuatus*. In summary, there are not enough Naungkangyi specimens of *Porambonites* to identify the species with confidence, and it appears that there may be three or even more different species in our material.

Superfamily **LISSATRYPOIDEA** Twenhofel, 1914
Family **PROTOZYGIDAE** Hall & Clarke, 1893
Subfamily **PROTOZYGINAE** Hall & Clarke, 1893

Genus ***PROTOZYGA*** Hall & Clarke, 1893

Protozyga? haydeni Reed, 1936

1936 *Protozyga haydeni* Reed: 51, pl. 4, fig. 12.

DISCUSSION. Although there are no atrypoids in our new material, a distinctive dorsal valve from rocks corresponding to the Naungkangyi Group at Taunggyi in the Southern Shan States, was illustrated by Reed (1936: 51) as *Protozyga haydeni*. This was reassessed by Copper (1986: 834) as *P.? haydeni* Reed and we agree. In addition, Reed also figured a single pair of external moulds (1936: 52, pl. 5, figs 9–10) from the same locality and horizon as *P.? haydeni* which he identified as *Protozyga?* cf. *obsoleta* Foerste, but which we consider unidentifiable.

Subfamily **CYCLOSPIRINAE** Schuchert, 1913

Genus ***CYCLOSPIRA*** Hall & Clarke, 1893

Cyclospira sp.

?1932 *Hyattidina* sp. Reed: 206, pl. 3, figs 17–18.
1936 *Cyclospira?* sp. Reed: 52, pl. 4, fig. 13.

DISCUSSION. Reed (1936) figured a ventral valve as *Cyclospira?* sp. from rocks corresponding to the Naungkangyi Group at Taunggyi in the Southern Shan States. Although Reed's identification queried the genus, it appears from Reed's figures that the specimen should be included within *Cyclospira*. Ventral and dorsal valves from rocks corresponding to the Naungkangyi Group at Taunggyi, Southern Shan States, figured by Reed (1932) as *Hyattidina* sp., might also be included here.

ACKNOWLEDGEMENTS. We thank A.H.G. Mitchell and B.J. Amos for the new collections, which they presented to the Natural History Museum, and to R. B. Rickards for the loan of material from the Sedgwick Museum, Cambridge. ZRB acknowledges a grant from the Academia Sinica to undertake the work at the Natural History Museum. Thanks to P. Crabb, NHM Photo Unit, for photography.

REFERENCES

Bancroft, B.B. 1928. On the notational representation of the rib-system in Orthacea. *Memoirs and Proceedings of the Manchester Literary and Philosophical Society*, **27** (5): 53–90, pls 1–3.

—— 1945. The brachiopod zonal indices of the stages Costonian to Onnian in Britain. *Journal of Paleontology*, Tulsa, **19** (3): 181–252, pls 22–37.

Bender, F. 1983. *Geology of Burma*. 293 pp. Beitrge zur Regionalen Geologie der Erde, Berlin.

Boucot, A.J. 1975. *Evolution and Extinctian Rate Controls*. 427 pp. Elsevier, Amsterdam.

Burrett, C.F., Long, J.A. & Stait, B.A. 1990. Early-Middle Palaeozoic biogeography

of Asian terranes derived from Gondwana. *Memoirs of the Geological Society of London*, **12**: 163–174.

Cockerell, T.D.A. 1911. The name *Glossina*. *Nautilus*, **25**: 96.

Cocks, L.R.M. 1978. A review of British Lower Palaeozoic Brachiopods including a synoptic revision of Davidson's monograph. *Monograph of the Palaeontographical Society*, London. 256 pp.

—— **& Fortey, R.A.** 1990. Biogeography of Ordovician and Silurian faunas. *Memoir of the Geological Society*, London, **12**: 97–104.

—— **& ——** 1997. A new *Hirnantia* fauna from Thailand and the biogeography of the latest Ordovician of South-east Asia. *Geobios*, **20**: 111–120, pls 1–2.

—— **& Rong Jia-yu** 1989. Classification and review of the brachiopod superfamily Plectambonitacea. *Bulletin of the British Museum (Natural History)*, London, Geology **45**: 77–163.

Cooper, G.A. 1956. Chazyan and related Brachiopods. *Smithsonian Miscellaneous Collections*, Washington, **127**: 1–1245, pls 1–269.

Copper, P. 1986. Evolution of the earliest smooth spire-bearing atrypoids (Brachiopoda: Lissatrypidae, Ordovician-Silurian). *Palaeontology*, **29**: 827–866, pls 73–75.

Davidson, T. 1853. British fossil Brachiopoda, vol. 1, Introduction. *Monograph of the Palaeontographical Society*, London. 136 pp, 9 pls.

—— 1966–71. The Fossil Brachiopoda, **3**, Silurian. *Monograph of the Palaeontographical Society*, London, 397 pp, 50 pls.

Foerste, A.F. 1909. Preliminary notes on Cincinnatian fossils. *Bulletin of the Denison University Scientific Laboratories*, Ohio, **14**: 209–230, pls 1–4.

Fortey, R.A. & Cocks, L.R.M. 1998. Biogeography and palaeogeography of the Sibumasu Terrane in the Ordovician: a review. *In* Hall, R. and Holloway, J.D. (eds), *Biogeography and geological evolution of South-East Asia*. Backhuys, Leiden: 43–56.

Fu Li-pu 1982. Brachiopoda. *In* Xi'an Institute of Geology and Mineral Resources (ed.), *Palaeontological Atlas of Northwest China, Shaanxi-Gansu-Ningxia*, **1**: 95–178, pls 30–45. Geological Publishing House, Beijing (in Chinese).

Garson, M.S., Amos, B.J. & Mitchell, A.H.G. 1976. The geology of the area around Neyaungga and Ye-ngan, Southern Shan States, Burma. *Memoir of the Institute of Geological Sciences Overseas*, **2**: 1–70.

Hall, J. 1847. Natural History of New York – containing descriptions of the organic remains of the lower division of the New-York System. *New York State Geological Survey, Palaeontology of New York*, Albany, **1**: 1–338, pls 1–87.

—— **& Clarke, J.M.** 1892–94. An introduction to the study of the genera of Palaeozoic Brachiopoda. *New York State Geological Survey, Palaeontolgy of New York*, Albany, **8**: part 1: 1–367, pls 1–41; part 2: 1–394, pls 42–84.

Heinrichson, T. 1932. Über *Porambonites wahli* n. sp., aus der Ordovizischen Johvi-Stufe D_1 Estlands. *Eesti Loodusteaduse Arhiiv*, Tartu, **10**: 157–166, pl. 2.

Holmer, L.E. 1989. Middle Ordovician phosphatic inarticulate brachiopods from Västergtland and Dalarna, Sweden. *Fossils and Strata*, Oslo, **26**: 1–172.

Hurst, J.M. 1979. The stratigraphy and brachiopods of the upper part of the type Caradoc of south Salop. *Bulletin of the British Museum (Natural History), Geology*, London, **32** (4): 183–304.

Jaanusson, V. & Bassett, M.G. 1993. *Orthambonites* and related Ordovician brachiopod genera. *Palaeontology*, London **36** (1): 21–63, pls 1–9.

Jin, J. & Norford, B.S. 1996. Upper Middle Ordovician (Caradoc) brachiopods from the Advance Formation, northern Rocky Mountains, British Columbia. *Bulletin of the Geological Survey of Canada*, **491**: 20–77, pls 1–13.

Jones, O.T. 1928. *Plectambonites* and some allied genera. *Memoirs of the Geological Survey of Great Britain, Palaeontology*, London, **1** (5): 367–527, pls 21–25.

King, W. 1846. Remarks on certain genera belonging to the class Palliobranchiata. *Annals and Magazine of Natural History*, London, (1) **18**: 26–42.

Klenina, L.N., Nikitin, I.F. & Popov, L.E. 1984. *Brachiopods and biostratigraphy of the Middle and Upper Ordovician of the Chinghiz ranges*. Alma-Ata. 196 pp, 20 pls (in Russian).

Kozlowski, R. 1929. Les brachiopodes gothlandiens de la Podolie Polonaise. *Palaeontologia Polonica*, Warsaw, **1**: 1–254, pls 1–12.

Kulkov, N.P. & Severgina, L.G. 1989. *Ordovician and Early Silurian Stratigraphy and Brachiopods from Gorny Altai*. Nauka, Moscow. 221 pp., 32 pls (in Russian).

La Touche, T.H.D. 1913. Geology of the Northern Shan States. *Memoirs of the Geological Survey of India*, **39**(2): 1–379, pls 1–27.

Menke, C.T. 1828. *Synopsis methodica molluscorum generum omnium et specierum earum quae in Museo Menkeano adservantur*. 91pp. Pyrmonti.

Metcalfe, I. 1992. Ordovician to Permian evolution of Southeast Asian terranes: NW Australian Gondwanan connections. *In* Webby, B.D.E. & Laurie, J.R. (eds), *Global perspectives on Ordovician Geology*: 293–305. Balkema, Rotterdam.

Mitchell, A.H.G., 1981. Phanerozoic plate boundaries in mainland S. E. Asia, the Himalayas and Tibet. *Journal of the Geological Society of London*, **138**: 109–122.

—— **Marshall, T.R., Skinner, A.C., Baker, M.D., Amos, B.J. & Bateson, J.H.** 1977. Geology and exploration geochemistry of the Yadanatheingi and Kyaukme-Longtawkno areas, Northern Shan States, Burma. *Overseas Geology and Mineral Resources Report*, **51**: 1–35. Institute of Geological Sciences, London.

Nikitin, I.F. 1974. [New Middle Ordovician Plectambonitacea (Brachiopoda) from Kazakhstan]. *Paleontologicheskii Zhurnal*, Moscow, **1974**(3): 55–66, 2 pls (in Russian).

Öpik, A.A. 1930. Brachiopoda Protremata der Estlndischen Ordovizischen Kukruse-Stufe. *Acta et Commentationes Universitatis Tartuensis*, Dorpat, (A)**17**(1): 1–262, pls 1–22.

Pander, C.H. 1830. *Beitrge zur Geognosie des Russischen Reiches*. 165pp., 31pls. St. Petersburg.

Percival, I.G. 1991. Late Ordovician articulate brachiopods from central New South Wales. *Memoir of the Association of Australasian Palaeontologists*, **11**: 107–177.

Reed, F.R.C. 1906. The Lower Palaeozoic fossils of the Northern Shan States, Burma. *Palaeontologia Indica*, Calcutta, (NS) **2** (3): 1–154, pls 1–8.

—— 1915. Supplementary Memoir on new Ordovician and Silurian fossils from the Northern Shan States. *Palaeontologia Indica*, Calcutta, (NS) **6** (1): 1–98, pls 1–12.

—— 1917. The Ordovician and Silurian Brachiopoda of the Girvan District. *Transactions of the Royal Society of Edinburgh*, **51**: 795–998, pls 1–24.

—— 1932. Notes on some Lower Palaeozoic fossils from the Southern Shan States. *Records of the Geological Survey of India*, Calcutta, **66** (2): 181–211, pl. 3

—— 1936. The Lower Palaeozoic faunas of the Southern Shan States. *Palaeontologia Indica*, Calcutta, (NS) **21** (3): 1–130, pls 1–7.

Rong Jia-yu & Cocks, L.R.M. 1994. True *Strophomena* and a revision of the classification and evolution of strophomenoid and 'strophodontoid' brachiopods. *Palaeontology*, **37**: 651–694, pls 1–7.

——**, Li Rong-yu & Kulkov, N.P.** 1995. Biogeographic analysis of Llandovery brachiopods from Asia with a recommendation of use of affinity indices. *Acta Palaeontologica Sinica*, **34**: 428–453.

—— **& Zhan Ren-bin** 1996. Distribution and ecological evolution of the *Foliomena* fauna (Late Ordovician brachiopods). *In* Wang Hong-zhen & Wang Xun-lian (eds), *Centennial Memorial Volume of Prof. Sun Yunzhu: palaeontology and stratigraphy*: 90–97, pls 1–2. China University of Geosciences Press, Beijing.

Schuchert, C. 1893. A classification of the Brachiopoda. *American Geologist*, Minneapolis, **11**(3): 141–167.

—— 1913. Class 2. Brachiopoda. *In*: Zittel, K.A. von (transl. edit. Eastman, C.R.), *Textbook of Palaeontology*. **1** (2nd edition): 355–420, text-figs 526–636. London.

—— **& Cooper, G.A.** 1931. Synopsis of the brachiopod genera of the suborders Orthoidea and Pentameroidea, with notes on the Telotremata. *American Journal of Science*, New Haven, (5) **20**: 265–288, pls 1–3.

Twenhofel, W.H. 1914. The Anticosti Island faunas. *Museum Bulletin of Canada Geological Survey*, **3**: 1–35, pl. 1.

Ulrich, E.O. & Cooper, G.A. 1936. New genera and species of Ozarkian and Canadian brachiopods. *Journal of Paleontology*, Tulsa, **10**: 616–631.

—— —— 1938. Ozarkian and Canadian Brachiopoda. *Geological Society of America Special Paper*, New York, **13**: 1–323, pls 1–58.

Willard, B. 1928. The brachiopods of the Ottosee and Holston Formations of Tennessee and Virginia. *Bulletin of the Museum of Comparative Zoology*, Harvard, **68**: 255–292, pls 1–3.

Williams, A. 1962. The Barr and Lower Ardmillan Series (Caradoc) of the Girvan District, south west Ayrshire, with descriptions of the Brachiopoda. *Memoirs, Geological Society of London*, **3**: 1–267, pls 1–25.

—— 1963. The Caradocian Brachiopod Faunas of the Bala District, Merionethshire. *Bulletin of the British Museum (Natural History), Geology*, London, **8** (7): 327–471, pls 1–16.

—— **& Wright, A.D.** 1963. The classification of the '*Orthis testudinaria* Dalman' group of brachiopods. *Journal of Paleontology*, Tulsa, **37** (1): 1–32, pls 1–2.

Williams, A. *et al.* 1965. *Treatise on Invertebrate Paleontology, H. Brachiopoda*, University of Kansas Press, 927pp.

Winchell, N.H. & Schuchert, C. 1893. The Lower Silurian Brachiopoda of Minnesota. *The Geology of Minnesota, Minnesota Geological and Natural History Survey, Final Report*, **3**: 333–374 (Entire volume dated 1895).

Woodward, S.P. 1852. *A manual of the Mollusca; or rudimentary Treatise of recent and fossil shells*. xvi + 486pp., 24pls. London.

Wright, A.D. 1964. The Fauna of the Portrane Limestone; part 2. *Bulletin of the British Museum (Natural History), Geology*, London, **9**: 157–256, 11 pls.

Xu Han-kui, Rong Jia-yu & Liu Di-yong 1974. Ordovician Brachiopods. *In*: Nanjing Institute of Geology and Palaeontology, Academia Sinica (ed.), *Handbook of Stratigraphy and Palaeontology in Southwest China*, Beijing, 144–154, pls 64–66 (in Chinese).

Zhan Ren-bin & Cocks, L.R.M. 1998. Late Ordovician brachiopods from the South China Plate, and their palaeogeographical significance. *Special Papers in Palaeontology*, **59**: 1–70, pls 1–9.

APPENDIX

Rong *et al.* (1995) compared various affinity indices and found most useful those by Otsuka [AI=C/$(N_1N_2)^{1/2}$], Dice [AI=2C/(N_1+N_2)] and Fager [AI=C/$(N_1N_2)^{1/2}$–1/$(2(N_2)^{1/2})$]. In each formula N_1 is the total number of genera of one fauna, N_2 is the number of genera of another fauna and C is the number of genera common to both faunas, supposing N_2 is larger than N_1. We have calculated the affinity indices between the eight faunas by all three methods and Table 1 shows each index in the lower diagonal and their average in the upper diagonal. Below are the lists of faunas used in the calculation of affinity indices:

1. Shihtzupu Formation (early Caradoc), northwestern Guizhou, South China (Xu *et al.* 1974, with some additional material collected by R. P. Tripp in the Natural History Museum, London): *Philhedrella* sp.; *Lingulella* sp.; *Nicolella actoniae; N. delicata; Saucrorthis minor; Skenidioides* sp.; *Peritritoechia imbricatia; Gonambonites nobilis; Leptellina sinensis; Aegironetes minuta; Anoptambonites* sp.; *Chonetoidea* sp.; *Leptaena qianbeiensis; Platymena? mutabilis; Bellimurina rudis; Rafinesquina?* sp.; *Kiaeromena* sp.; *Glyptomena* sp.; *Syntrophopsis* sp.; *Porambonites triquetrus; P. transversus.*
2. Pingliang Formation (late Caradoc), Longxian, Shaanxi Province, Northwest China (Fu 1982, Rong & Zhan 1996): *Paracraniops* sp.; *Dolerorthis* sp.; *Bicuspina regularis; Glyptorthis* sp.; *Skenidioides* sp.; *Anisopleurella* sp.; *Leptestiina longxianensis; Leangella (Leangella)* sp.; *Sowerbyella* cf. *sladensis*; *Leptaena* sp.; *Gunnarella gigantea; Bellimurina quadrata; Kiaeromena longxianensis; Foliomena inelegans; Christiania longxianensis; Nubialba* sp.; indet. pentameroid; *Longxianirhynchia transversa; Cyclospira* sp.
3. Sargaldak Formation and its contemporary Anderken Formation (middle to late Caradoc), Chingiz, Kazakhstan (Klenina *et al.* 1984): *Ectenoglossa sorbulakensis; Tuvinia extrema; Archaeorthis opima; Productorthis* sp.; *Austinella grandis; Perimecocoelia semicostata; Aulie convexa; Sowerbyella rukavischnikovae; Ptychoglyptus* sp.; *Dulankarella* aff. *magna; D. namasensis; D. subquadrata; Craspedelia* sp.; *Leptaena (Leptaena) tarbagataiensis; Eoanastrophia extenuata; Camerella plicata; Rhynchotrema perspica.*
4. Khankhar Horizon (Caradoc), Gorny Altai, Russia (Kulkov & Severgina 1989): *Orthambonites jaboganicum; Altaeorthis uscutchevi; Hesperorthis concava; Boreadorthis togaensis; Glyptorthis altaica; G. balclatchiensis; Eridorthis subinexpecta; Multicostella (Chaulistomella) inaequistriata; M. (C.) amzassensis; Plectorthis apertus; P. altaicus; Plectorthis* sp.; *Mimella* sp.; *Severginella altaica; Paurorthis sibirica; Onniella chancharica; Triplesia mongolica; Palaeostrophomena* sp.; *Sowerbyites* cf. *lamellosus; Titanambonites elandicus; Isophragma ricevillense; Leangella scissa; Sowerbyella (Sowerbyella) sibirica; Bimuria bugrychiensis; Dactylogonia subgeniculata; Eoanostrophia lebediensis; E.* aff. *kurdaica; Togaella grandis; Rhynchotretoides aincus; Rostricellula lapworthi; R. ainsliei amzassica; R. exilis.*
5. Nant Hir Group and Derfel Limestone (Caradoc), Bala District, Wales (Williams 1963): *Lingulella* cf. *ovata*; *Pseudocrania* cf. *divaricata*; *Paracraniops macella; Orbiculoidea* sp.; *Orthambonites cessata; Nicolella actoniae; N. actoniae obesa; Dolerorthis duftonensis prolixa; Dolerorthis* sp.; *Dinorthis flabellulum; D. berwynensis; D. berwyensis angusta; Platystrophia* cf. *sublimis; Rhactorthis crassa; Skenidioides* cf. *costatus; Cremnorthis parva; Dalmanella modica; Howellites striata; H. intermedia; H. ultima; H. antiquior; Onniella ostentata; O.* cf. *soudleyensis; Bancroftina* sp.; *Reuschella* cf. *horderleyensis; R. horderleyensis undulata; Heterorthis alternata; H.* cf. *retrorsistria; Salopia* sp.; *Bicuspina spiriferoides; Oxoplecia* sp.; *Vellamo* sp.; *Leptestiina oepiki; Sowerbyella sericea; S. soudleyensis; S. musculosa; S. sericea permixta; Eoplectodonta* cf. *rhombica; Sericoidea* sp.; *Strophomena grandis; Strophomena* sp.; *Glyptomena* cf. *osloensis; Macrocoelia expansa; M. prolata; Hedstroemina?* spp.; *Leptaena salopiensis; L. ventricosa; Kiaeromena* cf. *kjerulfi; Bellimurina incommoda; Rostricellula sparsa; Cyclospira* sp.
6. Cliefden Caves Limestone Group and equivalents (Caradoc), central New South Wales, Australia (Percival 1991): *Hesperorthis barbata; Ptychopleurella decretoria; Eridorthis australis; Dinorthis hadra; Bowanorthis fragilis; Plectorthis cliefdenensis; Doleroides mixticius; Phaceloorthis decoris; Boonderella fasciculata; Skenidioides quondonensis; Paraonychoplecia inversa; Sowerbyites isotes; Wiradjuriella halis; Anoptambonites exedra; Tylambonites speciosa; Sowerbyella billabongensis; Oepikina? walliensis; Trigrammaria ampla; Quondongia alitis; Molongcola variabilis; Christiania skolia; Didymelasma inconspicua; Rhynchotrema oepiki; Protozyga definitiva; Webbyspira principalis; Zygospira carinata; Australispira disticha.*
7. Advance Formation (Caradoc), northern Rocky Mountains, British Columbia, Canada (Jin & Norford 1996): *Plaesiomys* aff. *subquadratus; P. meedsi; Dinorthis* cf. *holdeni; Glyptorthis assimilis; Scaphorthis perplexa; Platystrophia colbiensis; Paurorthis ponderosa; Paucicrura rogata; Oxoplecia globularis; Glyptambonites musculosus; Leangella (Leangella) biseptata; Christiania subquadrata; Bimuria* cf. *superba; Thaerodonta redstonensis; Eoplectodonta (Eoplectodonta) alternata; Strophomena* cf. *planumbona; Rafinesquina praecursor; Murinella* cf. *biconvexa; Oepikina* sp.; *Parastrophina* sp.; *Hiscobeccus mackenziensis; Anazyga bellicostata.*